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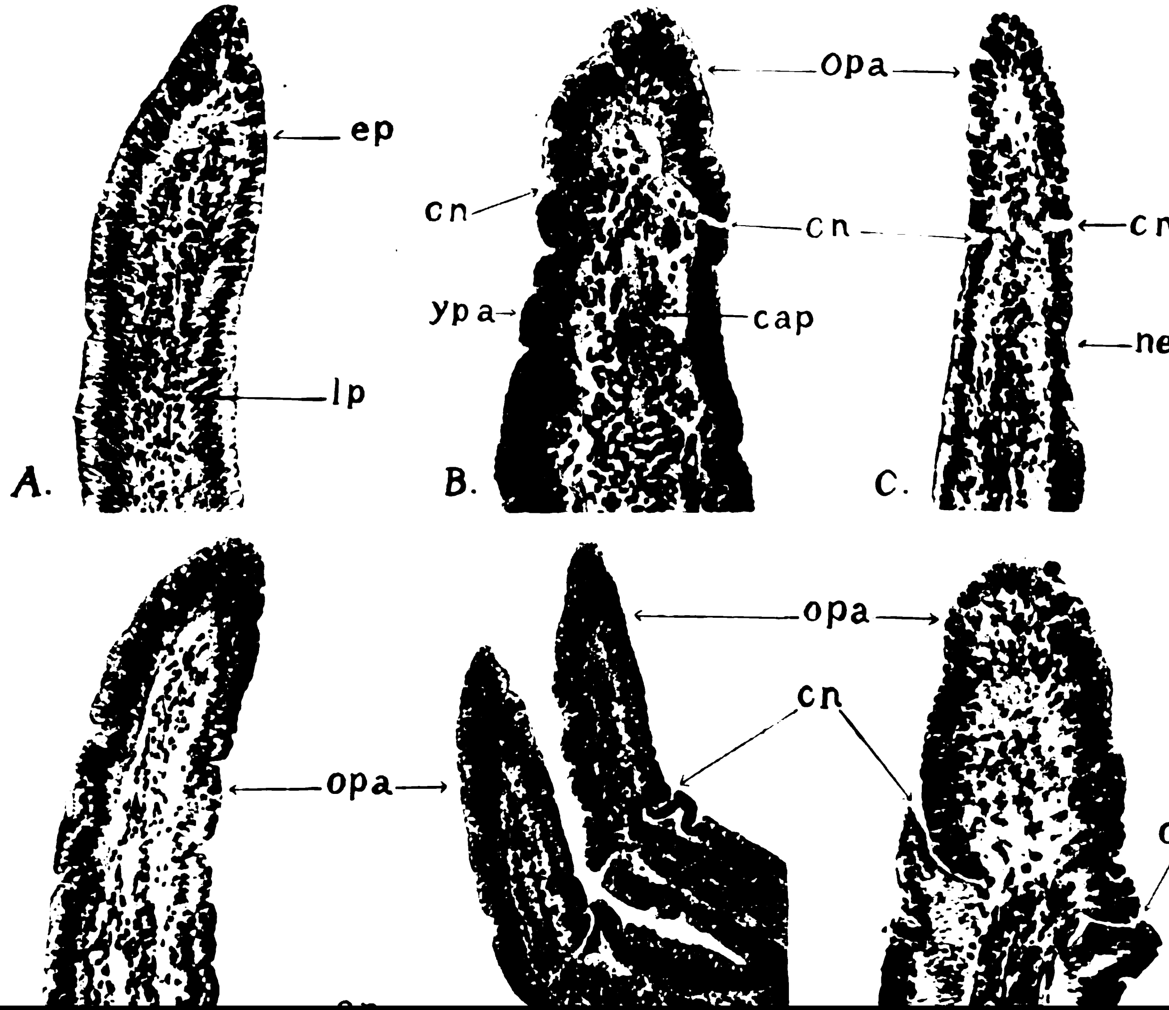

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Report on Norwegian Fishery- and Marine-Investigations Vol. I. 1900 No. 2.

HYDROGRAPHIC-BIOLOGICAL INVESTIGATIONS

OF

THE SKAGERRAK AND THE CHRISTIANIA FIORD

BY

JOHAN HJORT AND H. H. GRAN

KRISTIANIA
OSCAR ANDERSENS BOGTRYKKERI
1900

1.

The Skagerrak.

The hydrographical character of the Skagerrak is determined by its forming the connection between the Cattegat and the North Sea, or between the Baltic and the Atlantic. The central, and Northern part of the Skagerrak, forms a continuation of the Norwegian depression which there attains its greatest depth. Along the coast of Jutland and Bohuslæn, the bottom slopes gradually downwards, as will be seen from the following account. From the Swedish coast of the Skagerrak, the depth of 50 fathoms is not reached for 8 geographical miles off land; and the same depth off the Jutland coast is not to be found, as a rule, for over 20 miles. The curve of soundings, for a depth of 100 fathoms, cannot be met with under 14—16 miles off Bohuslæn, and 24—32 miles to the north of Jutland.

Review from earlier investigations

All along the Norwegian side, however, this curve is found at about 4 miles's distance from the shore, between Lindesnes and Jomfruland. At Langesund there is a deep depression extending still closer towards land, while, further North, however, the sea is shallower, and, outside the Christiania Fiord, only isolated depressions are to be found attaining a greater depth than 100 fathoms.

The different currents on the surface of the Skagerrak, are, mainly, dependent on causes which originate beyond the Skagerrak itself. From the Baltic, for instance, there flows a constant stream of brackish water, which keeps, chiefly, to the coast of Sweden, and which, at Koster, turns towards the Norwegian side. During the greater part of the year, at all events, it runs further along the coast from Svenør to Lindesnes.

On the charts of the Geographical Survey, this current, is plainly marked, and is, moreover, well known to all seafaring people. Professor Mohn has estimated its velocity at 10 geographical miles in 24 hours, 0.22 metres a second ([87]* page 168).

Again, on the coast of Jutland, there is a still stronger current, the so-called «Jutland Current», flowing into the Skagerrak, which, like the former, has been known to seamen for generations. According to annual observations, made on board Danish Lightships, and Mohn's theoretical calculations, the average speed is 18 geographical miles in 24 hours, 0.38 metres a second (Mohn l. c. p. 168). Even this is a coastal current, forming a continuation of those North Sea coastal currents which, of late, have been subjected to most accurate investigations by *Fulton* [97].

Investigations of the deep lying currents, long proved very difficult by the old methods, viz., the direct registration of the current. However, thanks to the services of Swedish hydrographers, a new method has been introduced, and generally adopted, by which one may, at any time, ascertain the hydrographical situation on the surface, as well as in deep water. The method consists in the determination of a layer's origin by investigating its salinity and temperature, it being known that layers of different salinities are of so different a specific gravity, that they move, the one below the other, for great distances and length of time, without intermixing. Pettersson and Ekman found, that all water in the Skagerrak of a lower salinity than 30⁰/₀₀, comes from the Baltic with *the Baltic Current;* furthermore, that water, exceeding 32 ⁰/₀₀ salinity, originates from the North Sea and the Atlantic Ocean. .

The Jutland Current, according to their investigations, brings a preponderate quantity of water, with a salinity of 32—34 ⁰/₀₀ *(Bank water)*, into the Skagerrak.

In the deep-water regions of the Skagerrak vast bodies of water are found in which the salinity exceeds 35 ⁰/₀₀. This water, being connected with the Gulf Stream, enters the Skagerrak as an under current through the Norwegian depression. Also those layers whose saline contents range from 34 to 35 ⁰/₀₀ (the so called *North Sea Water*) proceed from oceanic sources.

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*) [ ]. This form of brackets, with figures inside, indicates the date of literary publications, *vide* the Bibliography.

Pettersson and Ekman have given these results in their fundamental work: «Grunddragen af Skageracks och Kattegats Hydrografi», [91] the exactitude of which has been proved by all succeeding researches.

By means of these statements, one may arrive at a far more comprehensive understanding of the hydrographical character, than was, previously, possible. According to earlier experiments, one had to be content with a survey of the average distribution and strength of the oceanic currents, and of the mean temperature of many years, during each month of those years, &c. &c.

In applying the method of Pettersson & Ekman, it is possible to ascertain the hydrographical situation at any time. Thus one may follow the changes throughout the year, as the different currents increase or diminish in strength and thickness.

Pettersson & Ekman shew [91], that the distribution of the water-layers in the Skagerrak do change, according to the time of year. The Baltic current is found to be very extensively diffused during Summer, covering the entire surface of the Skagerrak with a warm layer of low salinity, extending to a depth of some 20 metres. Simultaneously, the Atlantic under current, of 35 ‰ salinity, rises to a depth of 50 métres from the surface, even close to the shore.

The Bank Water, however, at that time of year is but slightly represented, being met with in thin layers along the coasts, and, in the central parts of Skagerrak, may be entirely wanting, so that the Baltic layers rest, directly, on the 34 ‰ water.

During the course of the autumn, the Baltic current decreases, and is surplanted by considerable quantities of Bank water in the Skagerrak. As the final result of these interchanges, it may be seen that, in November, the entire surface becomes covered with a layer of bank-water to a depth of 20—30 metres, while the remainder of the Baltic water is forced up into the Northern, and Eastern part of the Skagerrak. Coincident with this, the 35‰ water's level sinks over the whole of the Skagerrak, particularly along the coast, not even surmounting the banks off the Swedish coast. This condition is generally maintained during the winter, and, not until May, does the Baltic current overcome the Bank-water, which partly flows away, and, partly, remains as under currents below the Baltic layers.

The surface water of the Skagerrak thus changes twice a year, in

May and November. These changes in the waters, which, according to Pettersson's and Ekman's recent experiments may, possibly, appear still more complicated than represented by us, seems to be closely connected with the gradual approach of the herring to the shores of the Skagerrak.

G. Ekman could, even in 1878, perceive that the approach of the herring, off the Bohuslæn (26—28 December), occured directly after the expansion of the Bank-water. Pettersson and Ekman also publish several observations which indicate, that the herring come in with the Bank-water layers, but, that a great accumulation of Baltic water prevents the herring from approaching the shore.

It was most requisite, and of great interest, to see if such hydrographical variations really took place from one year to another, in order that the great irregularities of the herring fisheries might be, thereby, explained.

All researches made in the Skagerrak during the interval (1893 97), by the Swedes and Norwegians, have, therefore, been mainly directed towards solving the question, whether the gradual approach of the herring towards Bohuslæn, and the south east coast of Norway, can be connected with the influx of the Bank-water.

In order to obtain a more comprehensible view of these hydrographical conditions, at different periods of the year, it would be necessary, so far as is possible, to make *simultaneous* observations throughout a large area of water.

The Swedish and Norwegian Hydrographers have, therefore, worked in cooperation. Surface observations have been procured through the kindness of private Steamship Companies, and deep water observations, have, in some instances, been made, at one and the same time, in both countries.

When, in the present work, we, are about to give an account of the Norwegian investigations and their results, we must, also, menter into the details of the work performed by the Swedish scientists.

Hjort in his treatise «Hydrographic-biological studies of the Norwegian Fisheries» [95], has given an account of his labours during 1893—94.

The Swedish Hydrographers have published several papers on this subject, but the principal results are given in Pettersson and Ekman's treatise [97]: «De hydrografiska förändringarne inom Nordsjöns och Östersjöns område under tiden 1893—1897».

Pettersson and Ekman, in their first endeavours [91] towards solving the origin of the water layers, laid special weight on determining their temperature and salinity.

Since then another method has been largely adopted, viz., determining the origin of the water from the organisms it contained. The algæ have been determined by *Cleve*, who has issued several publications concerning them [94, 96, 97], and the animals by *Aurivillius* [96, 98].

This method may, undoubtedly, in many cases, be adopted with favourable results, although a profound knowledge of the organisms, their life and distribution, be required.

When, in the autumn, southern organisms are found in the Skagerrak, which are absolutely extraneous (as for instance *Pilema octopus*, *Loligo Forbesi*), one has unequivocal proof of currents entering from the southern oceanic regions. Thus, in a like manner, it must be assumed that northern organisms, such as *Clione limacina*, *Calanus hyperboreus* must be brought in by cold currents from the North.

One needs, however, to be very cautious in drawing these conclusions, as we have endeavoured to indicate in an account of the Northern Ocean [99]. The Swedish scientists not only determine the Baltic and Atlantic, southern and northern currents, by their organisms, but they also separate, in like manner, Western Atlantic, Central Atlantic and Eastern Atlantic waters, which enter the Skagerrak at different periods of the year, the one from the other.

As the distribution of the Plankton organisms in the Northern Atlantic throughout the year is, still, but little known, *Aurivillius*, l. c. p. 130 [98], had to arrange them in groups, chiefly in accordance with the period during which they remain in the Skagerrak. Species existing in the Skagerrak, from September to February (for instance *Plagiacantha arachnoides*, *Parathemisto oblivia*), are supposed to be brought by the so called Northern Bank-water from the Northern Ocean's eastern area of admixture off the Norwegian coast. Others, which are not found in the Skagerrak until November—December, and which remain in the surface layers until April—June, are supposed to originate from the West Atlantic area of admixture near the shores of Iceland and Jan Mayen (for instance *Tintinnus urnula*, *Fritillaria borealis*). Again, others may be observed in the surface layers of the Skagerrak from September to the months of May—June, which, otherwise, exist as well in the Eastern, as in the Western area of admixture, and probably also in the Arctic itself (*Tintinnus denticulatus*, *Pseudocalanus elongatus*, *Temora longicornis* and others).

This geographical classification, by Aurivillius, is based on the occurrence of Plankton Organisms in the Skagerrak, while their distribution in the Northern Ocean, and surrounding coasts, is but little known*. We therefore consider it rather premature to form *hypotheses*, concerning the origin of the water-layers in the Skagerrak, founded on these biological results.

In our opinion, it is of little advantage to set up, and carry out in detail a hypothesis on the different movements of the oceanic layers, while but little is known of the hydrographical and biological conditions of the Northern Atlantic at various periods of the year. We will therefore confine ourselves to acknowledging that, all the year round, a body of water from the North Sea makes its way into the Skagerrak, mainly through the Jutland surface current, and, as undercurrents, through the Norwegian depression.

Moreover, these volumes of water must, partly, originate from the English Channel, and partly from the northern entrance to the North Sea, between Scotland and the west coast of Norway.

When the inflowing water layers change their character with the seasons of the year, such may be explained by alterations in the Hydrographical and Biological conditions in the North Sea, and its two openings, during course of a year; but these alterations may be influenced by factors of a local character, without it being necessary that periodical changes take place in the entire system of the North Atlantic currents.

As already indicated, Pettersson and Ekman have shewn that, during the autumn, large quantities of *Bank-water* flow into the Skagerrak, and that these Bank-water layers, generally in November, force the Baltic water from the surface.

In the course of the autumn, the Bank water, being the warmest layer in the Skagerrak, retains, until the latter part of November, a temperature of 11°, and contains considerable quantities of southern organisms (*Pilema octopus*, *Loligo Forbesi*, *Rhizosolenia styliformis*, *Rh.robusta*, *Guinardia flaccida*, *Biddulphia mobiliensis*).

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*) The very valuable treatises on the Plankton of the Northern Ocean in 1898, of *Cleve* («Plankton collected by the Swedish Expedition to Spitsbergen in 1898», and «On the seasonal distribution of some Atlantic Plankton-Organisms»), and *Ostenfeld* (Iagttagelser over Overfladevandets Temperatur etc.) were not published when this was written.

It flows, to a great extent, along the coast of Jutland, then, subsequently, across to the Bohuslæn, where it partly runs as an undercurrent southward through the Cattegat, the remainder forming a coastal layer towards the entrance of the Christiania Fiord. From here, it, probably, moves down the south east coast of Norway. This Bank-water has a great influence on the Bohuslæn climate, like the Gulf Stream on the west coast of Norway; thus, for instance, one may find there, in Bohuslæn, some of the West European coastal vegatation, which, likewise, exists on the west coast of Norway from Lindesnes to Stadt, but which is entirely absent between, for instance, Lindesnes and Færder, where it cannot survive the severe winter-climate.

In 1893, the annual fluctuations took place, as described by Pettersson and Ekman, during good fishing years. 1893.

In November, Swedish investigations were made in the Skagerrak, while Hjort [95] examined the Norwegian Channel off Ekersund, the Hardanger Fiord, and the Sogne Fjord. By means of international cooperation, observations of the surface were simultaneously taken along the numerous steamship routes, in order that a complete surface map of the Skagerrak and the North Sea might be produced (see Pettersson and Ekman [97] pl. VI—VII, Hjort [95] pl. B.). The central and outer portions of the Skagerrak were covered with a Bank-water layer, of a thickness of about 30 metres, which drove back the Baltic water, to such an extent, that that formed but a narrow stripe along the coast of Sweden, and covered the Northern corner of the Skagerrak outside the Christiana Fiord.

We subjoin a profile (Fig 1), made by the Swedish Hydrographers on the 16th November 1893 (P. & E. [97] Pl. IX, Sect. 11), from Christiansand to Skagen *(The Scaw)*.

The Bankwater, and the subjacent 34°/oo water (The North Sea water), attained the highest temperatures, mostly 9—10°, while the surface water had commenced cooling; the deep Atlantic water, however, was, again, colder, its boundary, upwards, about coinciding with that of a temperature of 8°.

Fig 2, gives a section of the Gullmare Fjord in Bohuslæn (13—16. November), which, likewise, was made by Pettersson and Ekman. The Bank-water covered the bar of the Fiord, which prevented the layers of a higher salinity from entering. Thus, while the 34°/oo water outside the bar, was of a temperature of 10—11°, the layers inside, of the same salinity, were only about 4.5°.

The Plankton along the coast of Bohuslæn contained, according to

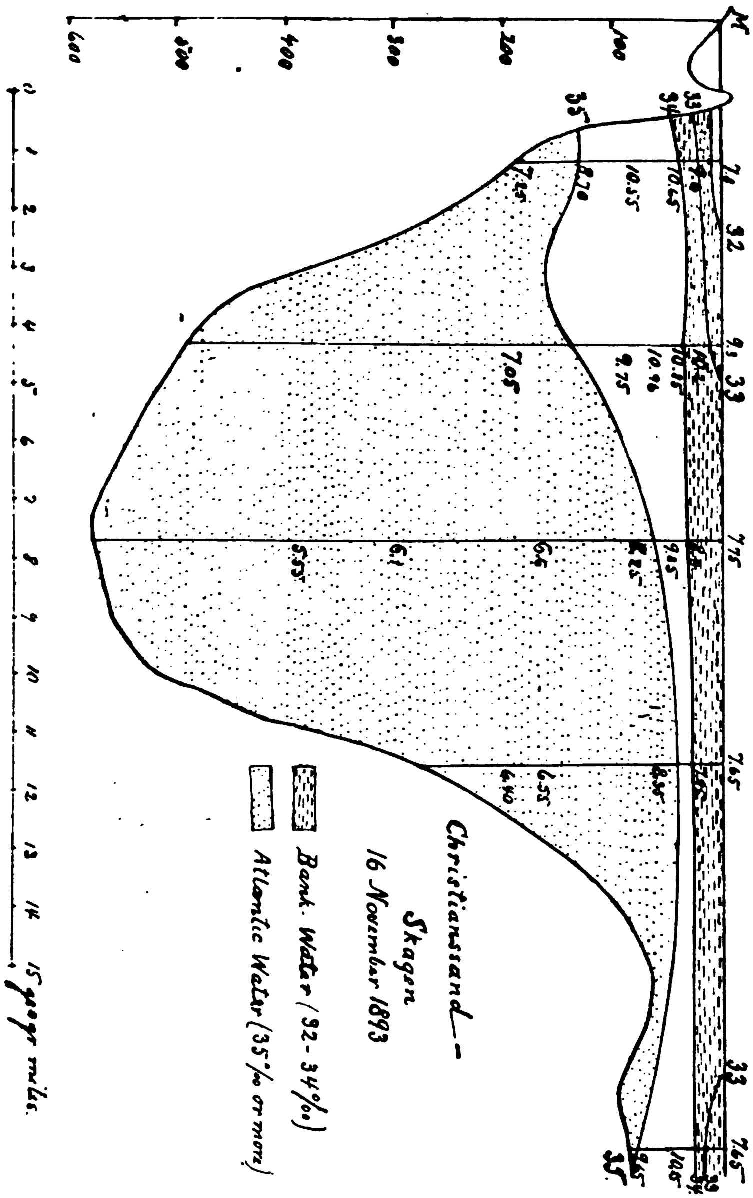

Fig 1. Copy of Pettersson and Ekman's chart.*

Cleve's investigations [94], great quantities of Diatoms; Neritic forms, of a southern origin, agreeing with Cleve's Didymus Plankton (*Chætoceras didymum, Ch. curvisetum, Ch. Schüttii*) predominating.

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*) «I geographical mile» in this and the following figures — 4 nautical miles.

A similar Plankton was, at the same time, found off Øster-Risør, at the Swedish Hydrographical Station S IX, and S X (Cleve l. c. p. 8—9), and at Vallø (Hjort [95] p. 41).

Wherever this Diatom Plankton was found in quantities, the surface still consisted of Baltic water from the preceding summer. On the other hand, where the Bank water reached the surface, for instance at the Swedish Stations S VII, and A XV, only small quantities of Diatoms were found, but, practically, the same species as those obtained at the other stations. (Cleve l. c. 8—9).

Off Ekersund, Hjort found a rich Plankton [95] p. 41, containing the same species of Diatoms (Didymus Plankton), but only as subordinate constituents, together with Crustacees, Chætognathes and Peridiniaceæ.

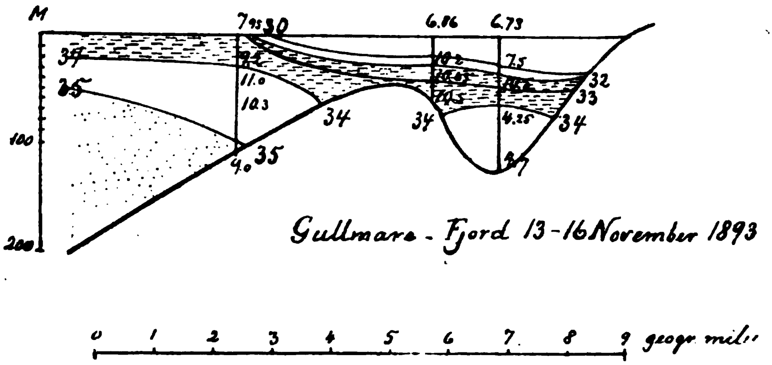

Fig. 2. Copy of Pettersson and Ekman's chart.

All this indicated, that the Neritic Diatoms had been developed during the summer, and autumn, on the surface of the inner Skagerrak.

In 1893, the herring fisheries proved exceptionally remunerative. The herring then advanced even in between the islands outside the Christiania Fiord. Off the coasts of the Skagerrak there was a take of more than 2 800 000 hektolitres. There must, consequently, have been particularly favourable conditions for the approach of the herring during that year.

In the autumn of 1894, international coöperative observations of the surface were undertaken; the results of which have been the production of a surface map for November, which also is published in Hjort's treatise [95] Pl. C. This map shews, that the spread of the Baltic layers was much greater than that of the previous year. 1894.

While the Baltic current, in November 1893, was confined to the Skagerrak and the Cattegat, it ran, in November 1894, all along our west coast, at several spots attaining a width of 16—20 geographical miles, the Bank-water being less represented than in 1893.

Outside the entrance of the Christiania Fjord, Hjort thus found, that (l. c. p. 26) the Baltic water layers obtained a depth of 50 metres, while, in 1893, they only reached to a depth of about 8—10 metres.

The herring did not then approach land, but remained out in the Skagerak. The Plankton, during that year, consisted, mainly, of Peridiniaceæ, while the Diatoms were only first found further out in the Skagerrak.

New Investigations in the Skagerak, Decr. 1896.

Still more divergent were the conditions in 1896. As the herring fisheries during that year proved a dead failure, the Swedish and Norwegian hydrographers made a joint exploration of the Skagerrak and the North Sea in the middle of December. In addition to the usual surface observations taken on the private Steamship Companies' routes, rich materials from the deep-sea investigations were, likewise, obtained, the Swedish scientists examining the S. Eastern part of the Skagerrak, while Hjort, from H. M. S. »Heimdal«, took observations on the lines, Christiania Fiord—Skagen (the Scaw), and Cattegat—Arendal.

All these investigations resulted in the publication of a popular reatise [97] by Cleve, Ekman, Hjort, and Pettersson. Since then the Swedish Hydrographers have published their researches in a more detailed report by Pettersson and Ekman [97].

Here we shall chiefly account for all that was accomplished by the Norwegians; this we cannot do, however, without, at the same time, mentioning the Swedish investigations.

The Norwegian material subjected to our observations is given in our Hydrographical Table I, and in the Plankton Table, No. 1.

The results prove that the Hydrographical conditions in 1896, really varied considerably from those of good herring years, such as 1893.

First of all it will be seen that the Baltic water covered almost the entire surface of the Skagerrak, extending to a depth of about 20 metres. It was only in the S. W. corner, and in a wedge along the shores of Skagen (the Scaw) that layers of high salinity could be found on the surface.

The Bank-water in 1896, was represented in comparatively less quantities, than usual, as thin layers under the Baltic waters, especially along the coasts where it was of much less extent than usual. Moreover it may be noticed, that the salt Atlantic water rose to an exceptionally high level, mainly on the coast of Sweden.

This is best seen from Fig. 3, which gives a profile of the Gullmare Fiord, reproduced from Pettersson and Ekman's. It shews that the Atlantic water has even crossed the bar of the Gullmare Fiord; otherwise it does not usually reach the coastal banks, and the bar of the fiord, during this period, is, generally, covered by Bank-water (see Fig. 2). Fig. 3 also shews the thinness of the Bank-water layer on the coast of Sweden.

The results of the Norwegian investigations of the Skagerrak are presented in Figs. 4 and 5. The former shews a section from Færder to Skagen (the Scaw), from which it is clear that the Baltic water (with a salinity up to 32^{0}/$_{00}$), covered the whole of the surface with a thin layer, whose temperature ranged from 2.^{0}5—3.^{0}5 on the surface. Only close to Skagen, (the Scaw) Station VI, did the warmer Bank-water reach the surfac (7.03).

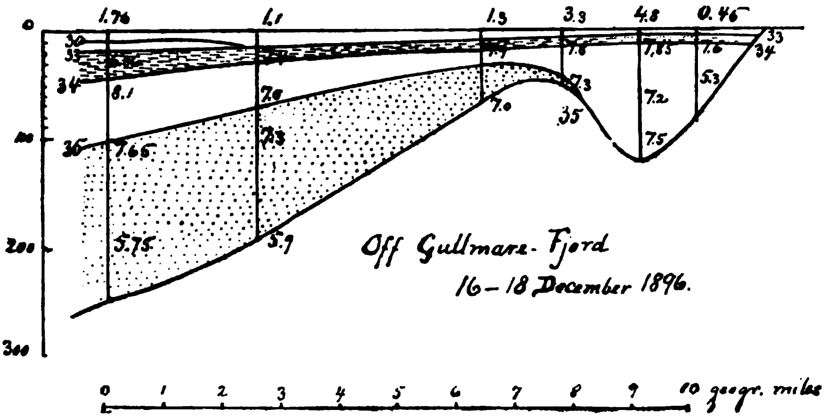

Fig. 3.

The highest temperatures, 8.^{0}5—9.^{0}5, lay at a depth of some 40 metres, about on a level with the isohaline for 34^{0}/$_{00}$, consequently on the boundary of the Bank-water and the North Sea water.

At Station VI, close to Skagen (the Scaw), no higher temperatures than 7.^{0}5 were met with, which shews, that the body of water flowing in with the Jutland current during that period, is colder than the warmest layers in the Skagerrak.

The maximum temperature in the Skagerrak, 9.^{0}7, was found off Hvaløerne (Station XV) at a depth of 20 metres; farther up the Christiania Fiord, at Vallø (Station XVI) even 10.^{0}3 was met with at the same depth. Some days later, Pettersson and Ekman found a temperature of 9.^{0}6 at 5 metres depth in the Gullmare Fiord, between Bornø and Holma. (l. c. p. 103), otherwise a temperature exceeding 9^{0}

was but rarely found in the Eastern part of the Skagerrak. The Atlantic water boundaries, on this section, will generally be found at a depth of 100 metres, except at Færder, (St. 1)where it rises to 70 metres below the surface

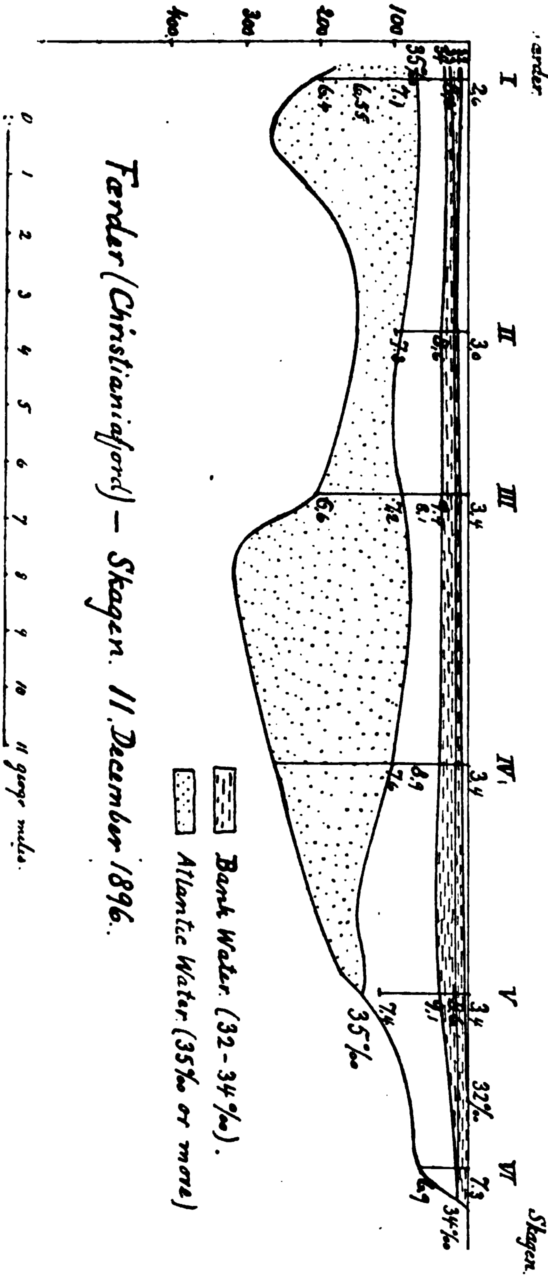
Færder
Skagen
I
II
III
IV
V
VI
100
200
300
400
35‰
32‰
34‰
Færder (Christianiafjord) — Skagen. 11. December 1896.
Bank Water (32-34‰).
Atlantic Water (35‰ or more)
0 1 2 3 4 5 6 7 8 9 10 11 geogr. miles.

Fig. 4.

If this section be compared with that of the Gullmare Fiord, (Fig. 3), and with the profile of Christiansand—Skagen (the Scaw), from November, 1893, (Fig. 2), it will be seen, that the Atlantic water in the central part of the Skagerrak, stands at a comparatively normal level; it is, thus, only along the eastern coast that an exceptional rise can be observed.

As is remarked by Pettersson and Ekman, this phenomenon may probably be explained as a reactionary or compensatory current, produced by the unusually strong, and lasting Baltic surface current.

The other section (Fig. 5) was taken from Arendal to the Cattegat, and runs to the north of Skagen. It is, furthermore, seen, that the Baltic water covered the whole surface; only at Station X, was it surplanted by the Bank-water.

The temperature on the surface was uniformly higher, about 5°. The Bank-water attained about the same thickness as on the former profile; at the eastern stations, the isohalines for 32‰ and 33‰, lay very close together; in other words, there was very little water containing a salinity of 32—33‰.

The Atlantic water, in the middle of the Skagerrak, at St. IX, rose up to the same depth (70 metres) as at Færder; off the coast of Jutland it did not even rise to the depth of 100 metres, nor even off Arendal. On the coast of Norway all these isohalines turn slightly downwards; consequently no rise of the subjacent layers had taken place, as was seen on the coast of Bohuslæn (Fig. 3) and, partly, at Færder. (Fig 4).

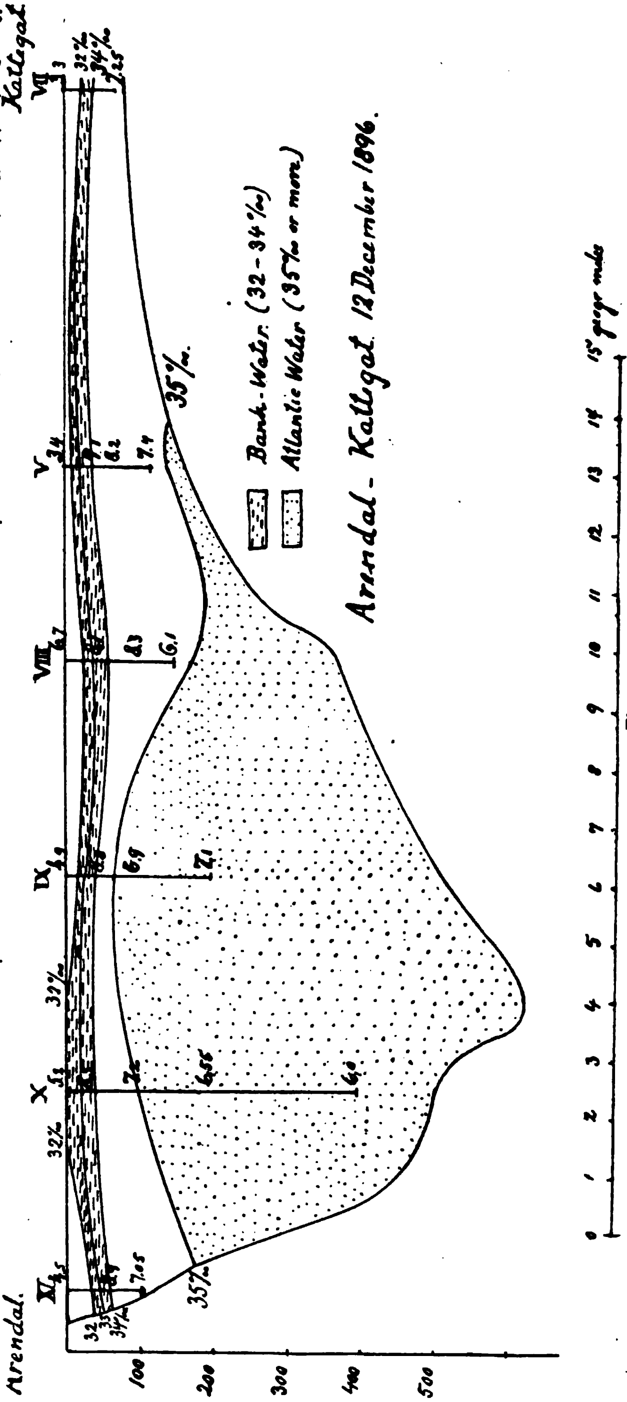

Fig. 5.

At that time of the year, the Skagerrak *Plankton* yielded very important information. Table 1 denotes a survey of the vegetable Plankton at all the hydrographical stations.

From this table one gets a strong impression of the exceptional similarity of the Plankton in all the surface layers of the Skagerrak; the same species being found, in greater or less numbers, in all the samples. On the other hand, there are certain stations which furnished a much poorer Plankton than all the others; the most remarkable being St. VI (Skagen), and Sts. XIX—XX. (in the inner portion of the Christiania Fiord); St. X had also an excessively poor Plankton. These are just the stations which had no Baltic water on the surface; at Skagen it had been displaced by salt water which had flowed in with the Jutland current; in the Christiania Fiord it was forced out by the prevailing northerly winds. This will, subsequently, be dealt with more closely by us.

Moreover at Station X, in the centre of the Skagerrak, the Baltic water was, likewise, supplanted by the Bank-water.

The same may be observed from the samples of Plankton, gathered by the Swedish hydrographers during the same period, and which have been examined by Cleve; the results being published in Cleve's great work [97] Table VII. He states, that more Plankton was found on the surface than at a depth of 15—30 metres; the surface consisted, mainly, of Baltic water, of a temperature not exceeding 4.°8; only at two Stations, *Ramsø* and «*W. of Väderø*» did the Bank-water reach the surface with a salinity of 33.3, and respective temperatures of 5.°6 and 6.°0. The Plankton samples from these stations were poorer, especially as regards diatoms, than any of the remaining surface samples. From this, one may safely conclude, that the rich vegetable Plankton belongs to surface layers of less salinity.

As the species are so evenly distributed all over the surface, it may be further concluded, that those water layers had remained on the surface of the Skagerrak for some length of time, so that the algæ had time to develop itself evenly, and become plentiful.

It is, however, another question, whether the germs of this abundant Plankton vegetation had been brought in with the oceanic currents, or if it had grown on the shores of the Skagerrak itself. To prove this, it will be necessary to examine, more closely, the species which appear most characteristic for the samples.

The samples contained both peridiniaceæ, and diatoms, in great quantities; of the former, the *Ceratium tripos* is the most prevalent, while the diatoms are represented, chiefly, by the oceanic species *Chætoceras boreale**, *Thalassiothrix Frauenfeldii*, and *longissima*, as well as by a number of neritic species, especially *Skeletonema costatum*. Amongst these the *Ceratium tripos* is so common, both in the Skagerrak, and the circumjacent waters at all times of the year, that no definite conclusions can be formed from its occurrence.

The Neritic Diatoms, probably, belong to the coasts of the Skagerrak itself. At that time of the year no large quantities of them are to be found, as the rich neritic autumnal plankton (*Didymus-plankton*) is then on the decrease, while species, which, in the cold season, form the other annual maximum, *the Sira plankton*, are not yet numerously represented. We find, however, species representing both these biological groups, but the main portion consists of species, which attain their maximum at periods differing from those of the two main maxima, viz., *Skeletonema*, *Thalassiosira gelatinosa*, and *Rhizosolenia setigera*.

Chætoceras boreale, and the *Thalassiothrix*, are oceanic species which *may* have entered with the inflowing currents from the North Sea. Cleve's Plankton Map of the North Atlantic [97] Pl. III, shews, that *Thalassiothrix longissima*, in the summer, has its greatest distribution in the N. Western part of the Atlantic, near the coast of Greenland, and Iceland (« *Tricho plankton* »), while *Chætoceras boreale* is supposed to originate from a wedge in the central part of the Atlantic, which runs in the direction S.W.—N.E., past the Faröe Islands.

There is, however, no ground for assuming that these species have been brought into the Skagerrak from the above mentioned places. It has recently been proved by us (Hjort & Gran [99]), that the oceanic diatoms are almost always sufficiently numerous in the North Atlantic, to develop into a rich plankton, under favourable circumstances. *Ostenfeld* has shewn (Wandel & Ostenfeld [98]), that the area between Scotland and Iceland, in May, contains a rich Diatom Plankton, but that very small quantities are to be found during the remainder of the year.

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*) ***Cleve*** has mentioned this form, which appears in these samples, under the name of ***Chætoceros boreale*** var. ***Brightwellii***; the characteristics which are said to distinguish it from the main species, are, however, of no systematic value, and in my opinion, it does not require any specific name. H. H. G.

The above named oceanic species, also exist in the Skagerrak in small quantities, nearly all through the year; it is therefore no easy task to decide, whether the main portion has, originally, come from outside, or if it has been developed in the Skagerrak itself. We have, however, already shewn, that, during December 1896, these species were found in the greatest numbers in the Baltic water layers which covered the surface of the Skagerak; while the North Sea, at the same time, had quite a different plankton (*Rhizosolenia styliformis*, *Coscinodiscus concinnus*, *Biddulphia mobiliensis*).

A similar Plankton seems to have prevailed on the surface of the Skagerrak, till later on in the winter; Cleve examined the Skagerrak, and North Sea Plankton in January 1897, the results of which are given in Table IX [97], and on the map, Pl. IV*).

He found great quantities of *Thalassiothrix longissima* in the Skagerrak, somewhat less of *Chætoceras boreale,* whilst the neritic species were but poorly represented, and mainly belonged to winter groups *(Thalassiosira Nordenskiøldii).* On his map, Cleve denotes the Skagerrak Plankton as a mixture of *Tricho-Plankton* and *Sira-Plankton (Thalassiosira).*

On the other hand, the North Sea continued to contain quite a different plankton, which more resembled the December plankton of the North Sea, than that of the Skagerrak *(Coscinodiscus concinnus, Biddulphia mobiliensis, Halosphæra, Peridiniaceæ).*

The change in the character of the plankton that took place from December to January, can thus hardly be due to any influx from the North Sea.

On the other hand, it might very well have arisen from a local development, as the species in December are nearly identical with those in January, the quantative character, only being somewhat altered.

Thalassiothrix, and the neritic winter forms, appeared to have increased in numbers, while *Chætoceras boreale* decreased, and the neritic autumn forms had almost disappeared. Furthermore, we think it possible that the changes, which took place in the plankton on the surface of the Skagerrak, from the summer till the beginning of December, may be owing to a gradual local development, though, we do not consider it improbable that oceanic forms were brought in from outside. The Plankton

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*) *Vide* Cleve l. c. Table VIII. The first 5 Stations are situated in the Skagerrak, the others in the North Sea.

Investigations thus lead to the same results as those obtained from the hydrographical studies, viz., that the surface layers of the Skagerrak remained stationary since the autumn; no changes of the water had occurred in November, as is generally the case during successful herring fishing years. In November 1893, the Bank water forced its way in, and covered the whole of the surface, forcing the Baltic water into the Norh Eastern corner, while, in the autumn of 1896, the Bank-water was exceedingly scarce in the Skagerrak.

In the above mentioned work [97], on the conditions of the Skagerrak during the then existing herring period, Cleve, Ekman, Hjort and Pettersson have endeavoured to prove, that those conditions caused the non-success of the herring fisheries during the autumn of 1896. They also state that the exceptional hydrographical conditions, during that year, were, probably, connected with the Meteorological, as the atmospheric pressure in the North of Europe, during the autumn, proved to be very high everywhere, with a succession of E. N. E. and S. E. winds in the Skagerrak and the North Sea.

That this was the case may be seen by comparing the annual report of the Norwegian Meteorological Institute in 1896 (Mohn [97]), with Mohn's Climatic Tables for Norway (»Klimatabeller for Norge»).

From these we find the average pressure in November, viz.,

	Average for 1866—95	1893	1896
Færder	757.2 mm.	755.2 mm.	762.5 mm.
Mandal	756.9 —	756.1 —	763.1 —
Skudenes	757.4 —	757.6 —	763.5 —
Bergen	755.7 —	756.0 —	761.2 —

	December Average	1893	1896
Færder	756.6 mm.	756.0 mm.	759.9 mm.
Mandal	756.5 —	755.9 —	759.1 —
Skudenes	756.6 —	755.0 —	758.3 —
Bergen	754.8 —	753.0 —	756.3 —

It will be seen that the atmospherical pressure at these Stations, that is, all along the Norwegian Skagerrak and North Sea coast, in November and December 1893, was practically normal, or just below the average.

During the same months in 1896, however, the pressure exceeded the normal by several millimetres, especially in November (5.3—6.2 mm), though rather less in December (1.5—3.3 mm.).

The atmospheric pressure at the same stations in January 1897, likewise appears to be 3.3—4.3 mm., above the normal, while in January 1894, it was 2.5—3.6 mm., below the average of the period 1866—95.

In addition to this, *Fulton* has found that the system of currents of the North Sea in December 96—January 97, went in an opposite direction to the general flow, on account of the incessant easterly, and south easterly winds. Thus, along the southern shores of the North Sea, the current ran in a westward direction, instead of the ordinary course towards the east, and north east.

It is evident that these circumstances must have affected the influx of the Bank water to the Skagerrak, as the in-going current along the coast of Jutland, is but a continuation of the coastal currents usually existing in the North Sea.

The perpetual north easterly winds must, further, have assisted in spreading the Baltic water over the entire surface of the Skagerrak; for short periods they even succeeded in forcing the Baltic surface water away from the northern part of the Bohuslæn coast, as is shewn on the surface map for December (Pettersson and Ekman [97] Pl. XII).

The north easterly winds indirectly caused the Atlantic deep water layers to be drawn so high up, along the east coast of the Skagerrak, in order to compensate for the out flowing surface currents.

The results arrived at by the four authors of the treatise »Skageraks tilstand» are, therefore, that, in the last instance, it was the meteorological conditions which caused the failure of the herring fisheries during the winter 1896—97.

Investigations Autumn 1897.

The hydrographical investigations in the autumn of 1897, were restricted to the north eastern corner of the Skagerrak, about the entrance to the Christiania Fiord.

It appears, from earlier researches, that the hydrographical conditions in the central part of the Skagerak are, comparatively, settled, while all changes are more marked in the neighbourhood of land. Along the shore there is a continual flow, while in the centre of the Skagerrak the water may remain stationary.

Langesund was chosen as the starting point of the Norwegian hydrographical investigations, partly because a branch of the deep channel in the Skagerrak advances there close to the shore, and, partly, on economical grounds, as the Association for Saving Life at Sea permitted investigations to be made from its vessel «Langesund», on her daily cruises.

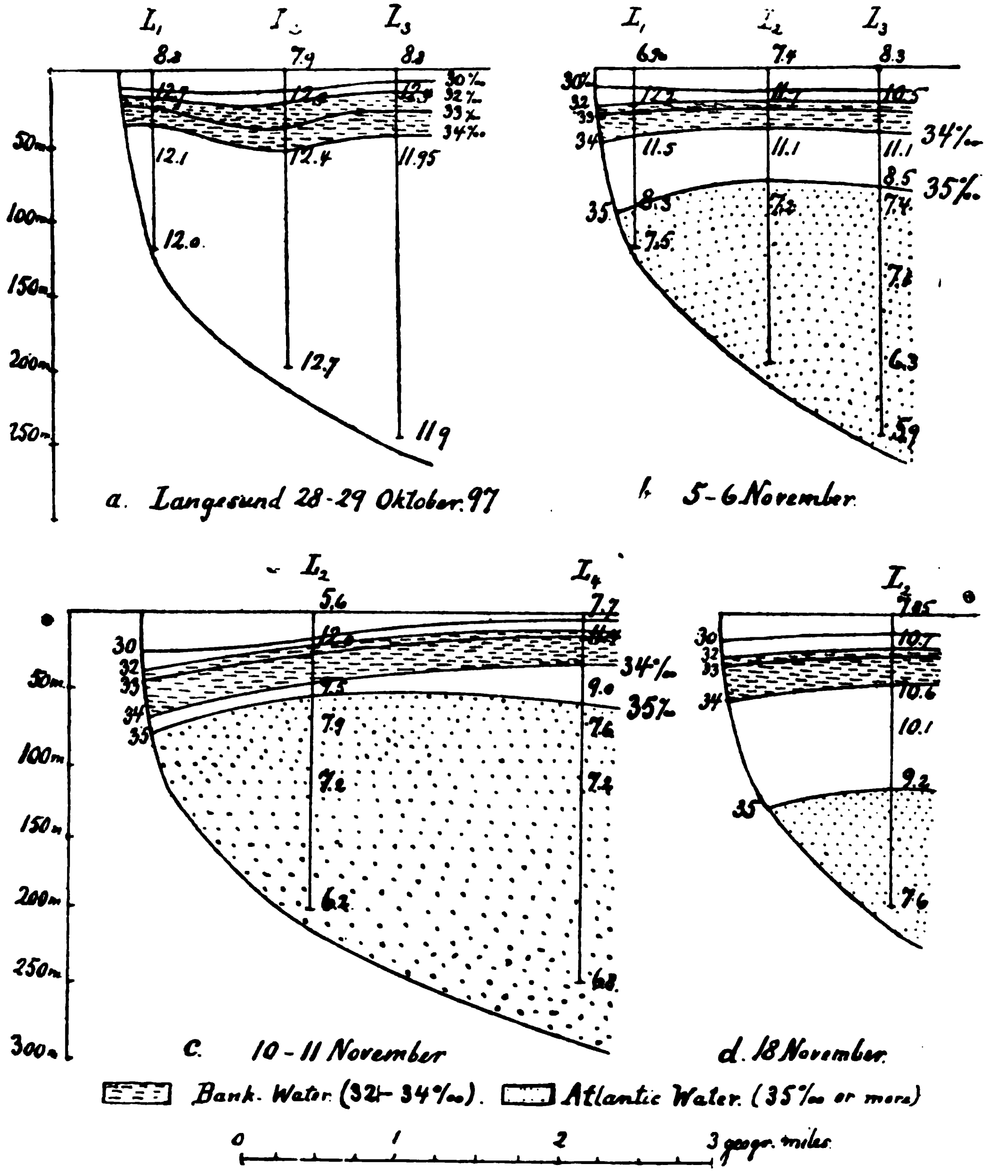

Fig. 6 a—f. Sections off Langesund — autumn 1897.*

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*) «1 geographical mile» on the figures = 4 nautical miles.

In this manner hydrographical profiles were obtained weekly, up to 10 geographical miles from the shore, from the 28th of October until the 4th of December.

The results of these investigations are given in the Hydrographical Tables II, A.—F, and on the Plankton Table 2. These shew, in a striking manner, that the hydrographical conditions along the coast, vary, to a great extent, with the meteorological conditions.

The first profile, taken on the 28—29 of October (Fig. 6 a.), shews that the Baltic water is 10—15 metres in thickness, below which, are the Bank-water layers of 20—30 metres in thickness; these seem to be thickest at Station L_2, 4 geographical miles from the shore. Below the Bank-water there is a thick layer, with a salinity of 34 ⁰/₀₀, but no Atlantic water was observed.

The temperatures were, universally, very high, 11—12°, though slightly colder on the surface. These thick, and warm layers cannot have been warmed at the spot; they must be of a southern origin, and must have been wedged in along the coast by the currents.

The Plankton mainly consisted of southern neritic forms (*Chætoceras contortum*, *didymum*, *Schüttii*), partly, also, of species capable of standing a low salinity, and which, therefore, may originate from the Cattegat and the Baltic (*Chætoceras danicum*, *radians*). Most remarkable is the appearance of *Rhizosolenia robusta*, an oceanic form belonging to warmer regions.

It is commonly found in the Mediterranean, and was, previously, never found further north than Plymouth. This Alga was undoubtedly, brought up with the southern currents. Its occurrence strengthens, still more, the hypothesis that, the warm water layers — the Bank water and the North Sea water, — are of extraneous origin. They, probably, have come with the Jutland current, which, every autumn, carries great quantities of southern organisms into the Skagerrak.

There was an essential change on the 5th and 6th of November (Fig. 6 b). The surface, it is true, was, as before, covered with Baltic water to a depth of about 20 metres, but the thickness of the Bank water, had decreased, considerably, while the warm 34⁰/₀₀ water had also diminished. At the outside stations, Atlantic water was found even at the depth of 80 metres.

The Bank water still retained a warmth of 12° or more, but the Atlantic water, which then filled the entire basin below 80—100 metres, was much colder. The isohaline for 35⁰/oo, almost coincides with the curve of 8°, and, in the deep, the temperature fell even to less then 6⁰.

The Plankton on the surface shewed no particular change from the previous week's observations. At Station L_3 a *Hensen* tow net was used, with a Petersen shutter, by means of which it was possible to ascertain the different kinds of plankton in the various layers.

Rhizosolenia robusta was still found in considerable quantities in the warmest layers (temperature above 11⁰), while the surface contained, mostly, neritic diatoms. At a depth of 5—15 metres *Rhizosolenia alata* was found in great quantities.

On the 10—11th of November (Fig 6 c), the Atlantic water had risen still higher, to but 60 metres below the surface, the Baltic-water being still of about the same thickness as before, but the warm, intervening layers had diminished, while the Bank-water and the North Sea water had become reduced, so that they together, at St. L_2, were only some 30 metres in thickness. Of the Plankton Diatoms, the Cattegat forms were somewhat more predominant than before (*Chætoceras danicum*). During the whole of that period, the atmospheric pressure on the Skandinavian peninsula proved exceptionally high, with fine weather, and northerly, or gentle N. E. winds. On the 11th November, however, the weather changed, together with a fall of atmospheric presssure, and, during the following days, strong south, to south westerly winds prevailed in the Skagerrak, the result of which was soon perceptible in the rise of both salinity and temperature on the surface; thus, on the 13th, Bie obtained at Station L_2, a surface temperature of 11⁰, and a salinity of 30.02 ⁰/oo. The gales had, thus, driven back the Baltic water layers and the water on the surface, therefore, was the same as was found, 3 days previously, at a depth of 15 metres.

As soon as weather permitted on the 18th of November, deep water examinations were made at Station L_2. (Fig. 6 d).

The Baltic water again covered the surface to a depth of 15 metres, but the Atlantic water had sunk to 120 metres below the surface. The 33⁰/oo, and chiefly the 34⁰/oo water, had increased in thickness, their total increase forming a layer of 60 metres. The temperature of the mixed layers was then somewhat lower than before, viz., about 10⁰. On the 18th, another outbreak of south westerly gales occured after but two days of calm weather. This time they lasted until the 23rd. On the 25th, renewed deep water investigations were made.

Fig 6 e, denotes a further increase in the thickness of the Bank-water, and 34°/oo water; the 33°/oo water at Station L_2, was about 50 metres thick, while the 34°/oo water appeared to reach right to the bottom; the temperature of these layers had then dropped to 9°.

Atlantic water was not observed at the outside stations, except at Station L_1, where it still remained, having probably, been prevented from receding by the belt of islands, and the prominent parts of the main land.

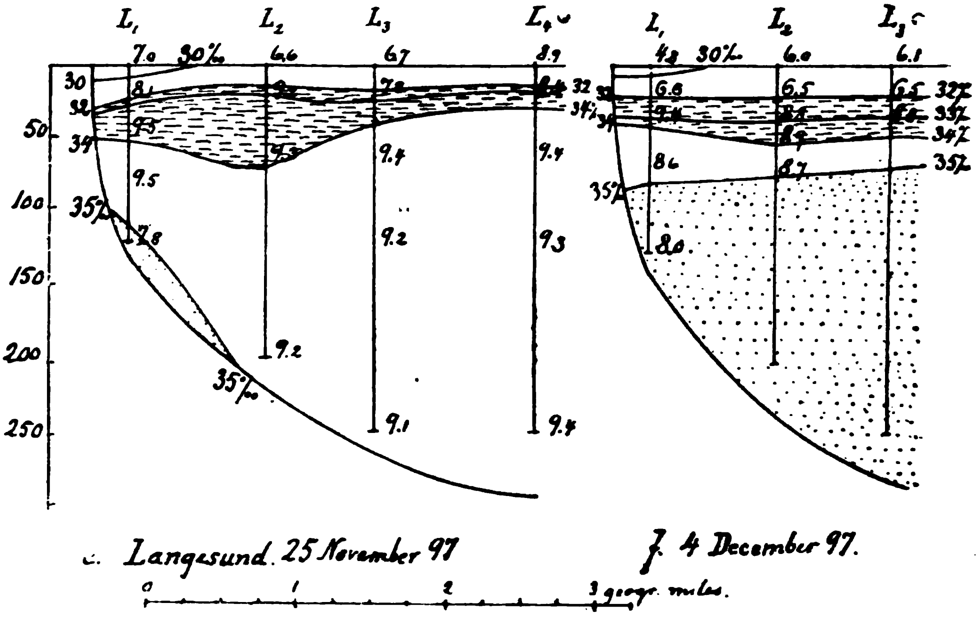

Fig. 6 e—f.

Simultanously with the hydrographical changes succeeding the south westerly gales, was the first approach of the herring towards «Hvaløerne», on the 25th of November, and to the coast of Bohuslæn, about the same time.

A good number were caught in the nets during the following days at the outermost fishing stations near «Hvaløerne». On the 30th, hydrographical investigations were carried on there, to which we shall soon refer, but shortly afterwards the situation became again changed, and the herring fishing ceased.

After a few days of northerly wind in the Skagerrak, the southwest winds returned on the 26th, and lasted till the 28th.

Our assistant, Bie, took observations at Langesund on the 30th, but only at one station, L_8; the result denoting that the Bank-water had further increased in thickness, its temperature being then about 8.$^{\circ}$5.

The observations at Langesund were ,however, discontinued on account of the persisting northerly winds, lasting from the 29th of November until the 4th of December. A profile was then made by Assistant Bie, (6 f), showing that the hydrographical conditions, characteristic of the first half of November, then, again, prevailed.

The Atlantic water was found at a less depth than 80 metres, the total thickness of the Bank-water and the North-Sea water being about 50 metres. At the same time the herring fishery at Hvaler terminated.

All these observations indicate that the hydrographical conditions along the coast vary extremely, and that the variations are closely connected with the nature and direction of the winds.

The Tables, given on the following page, will tend to create a still stronger impression of this fact.

On these we have given the daily observations (according to Mohn's Meteorological Journal [Jahrb. 97]) of the atmospheric pressure, direction and force of wind at 8 o'clock a. m., at Færder and Mandal, and for the same period that our observations at Langesund (28th October—4th December) were carried out.

We have italicized the different figures representing an atmospheric pressure *below* the normal pressure for the respective months throughout a long period (1866—95), as recorded by *Mohn* in his Climatic Tables [96].

Thus in October,	November,	December,
At Færder 767.0	757.2	756.6
» Mandal 756.6	756.9	756.5

We have, moreover, italicized the winds which might be regarded as sea winds; thus at Færder all south westerly and southern winds from WSW. to S., and, at Mandal, all western or southerly winds from WNW. to S.

Finally, in the third column there will be found simultaneous observations from *Skagens Rev,* of the direction of the current, its velocity and surface salinity. These observations we have obtained from the Danish Meteorological Institute's «Nautisk Meteorologiske Observationer» for 1897.

Station.		Færder.			Mandal.			Skagens Rev (Reef).		
	Date	Atmospheric pressure	Direction of wind	Force of wind	Atmospheric pressure	Direction of wind	Force of wind	Drift of current	Force of current	Sal per mill
Octr.	28	72.6	NNW.	0—1	71.7	E.	1	S.	1.5	25.1
	29	70.2	NNE.	1	70.2	E.	1	SSW.	0.7	28.6
	30	69.3	N.	1	70.2	NE.	1	*WSW.*	*1.5*	30.5
	31	69.0	WNW.	1	69.6		0	SSW.	1.0	29.3
Novr.	1	72.8	NW.	0—1	73.4		0	SSW.	1.7	25.9
	2	73.0	N.	1	73.2	NNE.	3	SSW.	1.3	26.7
	3	74.3	NNE.	1	75.3		0	SSW.	1.0	24.6
	4	75.8	N.	1	75.3	NNE.	2	S.	2.0	22.2
	5	70.7	*WSW.*	*1*	70.2		0	S.	2.0	22.7
	6	72.4	NNE.	2	71.6	NNE.	1	S.	3.0	23.8
	7	79.0	NE.	1	78.2	ENE.	2	SSW.	2.5	23.5
	8	76.1	NNE.	1	76.0		0	S.	1.0	23.7
	9	77.1	NNE.	1	76.6		0	S.	1.0	24.1
	10	79.2		0	78.3	SE.	1	S.	1.7	21.5
	11	73.2	*S.*	*2*	71.7	E.	1	SSW.	2.3	24.9
	12	62.8	*SSW.*	*2*	62.1	NE.	2	*SW.*	*0.5*	30.4
	13	*46.8*	*SSW.*	*3*	*47.0*	*SW.*	*3*	*W.*	*2.0*	*32.9*
	14	*51.0*	*SW.*	*2*	*51.5*	*SW.*	*2*	*W.*	*1.3*	*33.7*
	15	*43.3*	N.	3	*44.8*	*W.*	*1*	*W.*	*0.3*	*33.9*
	16	63.5	WNW.	2	66.5	NE.	1	S.	0.3	*33.1*
	17	65.3	E.	1	62.7	SE.	1		0.0	*32.8*
	18	*50.4*	*SSW.*	*2*	*53.4*	*WSW.*	*2*	*WNW.*	*1.3*	*32.3*
	19	*52.5*	*SW.*	*3*	*56.8*	W.	*3*	*W.*	*1.0*	*33.2*
	20	*56.1*	*WSW.*	*3—4*	63.1	*WNW.*	*2*	*WNW.*	*3.0*	*33.4*
	21	68.4	*W.*	*2—3*	71.5	*W.*	*1*	*WNW.*	*0.3*	*32.2*
	22	65.1	*WSW.*	*3*	69.8	*WSW.*	*2*	*W.*		31.2
	23	*56.8*	NW.	3	60.9	*NW.*	*1*	*W.*	*2.0*	30.9
	24	62.7	NW.	2—3	66.4		0	S.	0.5	31.3
	25	68.7	NNW.	2	70.1		0	S.	1.3	31.2
	26	65.9	*WSW.*	*2*	66.7		0	S.	1.5	30.7
	27	*49.4*	*WSW.*	*3*	*53 6*	*W.*	*1*	*NW.*	*2.3*	31.1
	28	*38.7*	*SW.*	*2—3*	*40.9*	*W.*	*2*	*WNW.*	*2.0*	*32.1*
	29	*35.5*	NNE.	3—4	*31.7*	NE.	4—5	*SW.*	*0.3*	31.5
	30	*41.8*	WNW.	1	*44.3*		0	NNE.	0.7	31.6
Decr.	1	*45.8*	NNE.	3	*44.5*	NE.	4	SSW.	0.3	*32.3*
	2	60.6	NNW.	3	63.0		0	S.	0 5	31.9
	3	67.7	NNE	2	68.4		0	S.	1.5	31.5
	4	67.8	NE.	1	67.9	NNE.	2	SE.	0.5	31.5

The lightship is so situated, that all currents from the south (SSE. to SSW.), come from the Cattegat while westerly currents (from WSW.—NW.) bring the surface water from the southern parts of the Skagerrak. We have italicized all currents that flow in from outside, that is, all currents from WSW. and NW.

Surface water, with a salinity exceeding 32⁰/₀₀, has been italicized, as such high salinity, according, to Pettersson and Ekman, is characteristic of the layers flowing into the Skagerrak from outside.

In this instance it is the *Bank-water* which is conveyed with the Jutland current past the Skagen lightship, while the Baltic surface water is carried in a northward direction by the currents from the south. It will be seen that the italicized parts of the table agree in all the columns.

Corresponding with the low atmospheric pressure, are the southern and south westerly winds; and, at Skagen, the inflowing currents get the upper hand, and force the Bank-water to the surface.

A high atmospheric pressure, on the contrary, results in calm weather, or off shore winds, and outflowing currents, containing Baltic water, may be found on the surface at Skagen. Thus during the abnormally high pressure, which prevailed from the 28th of October to the 12th of November, the currents at Skagen constantly flowed in an outward direction — the 30th, however, forming an exception — and Baltic water was found on the surface.

From these above mentioned facts, we may conclude that a smaller quantity of Bank water had entered the Skagerak than is usual at that time of the year. We observed, too, that the Bank water layers at Langesund, at that time, constantly became thinner, and that the Atlantic water from the depths of the Skagerrak was drawn, upwards, to compensate for the outflowing volumes of water.

The two gales from the 12th to the 15th, and from the 18th to the 23rd November, greatly added, however, to the increase of the Bank water at Skagen — the saline contents of the surface rising to 33.9 — while, at the same time, the thickness of the Bank water at Langesund increased, while the Atlantic water decreased.

The storm lasting from the 27th to 29th of November, caused a still further increase of the phenomenon, but, after that, the atmospheric pressure commenced to rise again, the current at Skagen flowed in an outward direction, and the Bank water decreased on the Norwegian coast. The first appearance of the herring on the coast of Norway, after the great south westerly gales, was observed at Hvaler on the 25th of November, where they arrived from the south coast of Sweden.

Hydrographical researches were made at Hvaler on the 30th (fig 7), Table II, G. The net fisheries were still continued, especially at Tisler and Heia. Station H1, is situated close to the best fishing grounds, in the channel between Tisler and Lauer. It will be seen that the Bank water there attained a great hight, about 5 metres below the surface, and was about 30 metres thick, the temperature being 9° and upwards.

Further to the westward, at Torbjørnskjær (St H3.), and off the Christiania Fiord (St H4), the Bank water was first met with at a depth of about 15 metres, and the temperature of the uppermost layers was lower throughout. Off Langesund, the temperature was even still lower during that period; (Table II F.); the Bank-water was found there at a depth of 10 metres.

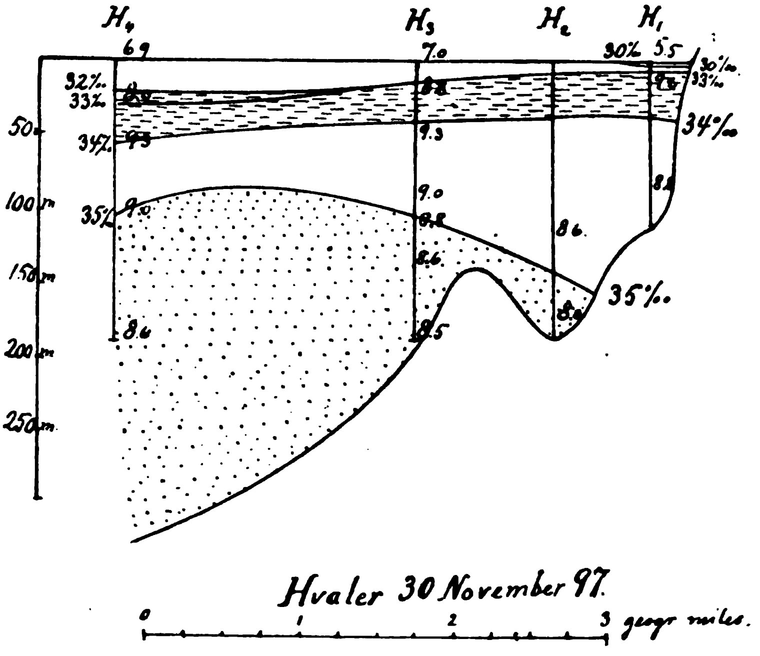

Fig. 7.

As soon as the change in the hydrographical conditions took place, so soon did the herring fishery at Hvaløerne cease.

With reference to the Plankton (see Table 2), the vegetable plankton remained, chiefly, in the upper layers, and showed no important change in its composition, although the hydrographical conditions of the deep may have been altered. The Plankton appeared to have undergone a gradual development during the autumn, the diatoms giving way to the peridiniaceæ, which then predominated.

The results thus arrived at from the investigations in 1897, respecting the herring fisheries, shew that the little approachments of the herring occurred, simultaneously, with a brief change in the hydrographical conditions. And as the results correspond with the experience gained from earlier years, it strengthens the hypothesis, that a connection exists between the approach of the herring, and the appearance of the Bank water along the coasts of the Skagerrak.

But the material at present to hand, is too inconsiderable to allow of a definite conclusion being formed. Still less easy is it to decide the question, as to how the herring-fisheries are dependent on the inflowing Bank water.

Hitherto the Swedes and Norwegians, in common, have succeeded in ascertaining that, the approach of the herring, during the last few years, has had a certain connection with the influx of Bank-water, and that, to a given extent, the number of herring has corresponded to the thickness of the Bank-water along the coast.

Furthermore, we have been able to shew that, the appearance of Bank-water along the coast is connected with the meteorological conditions. Little is yet known, however, as to the origin of the herring, or why it moves into the Skagerrak. So long as this remains a mystery, it is impossible, with any certainly, to foretell the future prospects from the basis of hydrographical investigations.

The hydrographical conditions along the coast of the Skagerrak are very variable, and the least factors will, in no time, suffice to cause great changes. It is, therefore, probable, that the great periodical fluctuations in the fisheries are founded on deeper grounds, and that the hydrographical changes viz., the struggle between the Bank water and the Baltic current, are but of secondary consideration.

The Swedish scientists (Pettersson, Ekman, Aurivillius) have set up the hypothesis that, the herring may be regarded as a plankton animal, drifting with a body of water like the crustacea etc., on which it lives.

The herring which makes its appearance in the Skagerrak during the summer and autumn, is, according to their presumption, brought in with the «Southern Bank-water» from the southern part of the North-Sea, while the Winter Herring, belongs to the «Northern Bank-water», which is supposed to proceed from the west coast of Norway.

Aurivillius states that the Summer Herring subsists on the southern plankton animals, while northern forms are found in the stomach of the Winter Herring.

A great deal might be said in favour of the supposition that the herring, during its migration in the Skagerrak, goes with the ocean currents.

All experience shows, that it first approaches the shore on the coast of Sweden, and then moves in a northward direction towards the the entrance of the Christiania Fjord. Only later on in the winter may it advance further westward, towards Arendal and Christiansand. This is the same course as that of the principal current of the upper layers, and if the herring follows this current, it will be constantly moving in the warmest layers of the Skagerrak, which, even at the end of November, are of a temperature of 9°, or more.

The distinction between the Autumn and Winter-Herring, is in our opinion, rather artificial, as would be the distinction between southern and northern Bank-water.

During the successful years, the fishing is pursued without interruption throughout the entire autumn, and no racial distinction between the shoals of herring has been proved as yet. That the Bank water is colder in December than in October, may, easily, be explained, even though it be assumed that the inflowing water layers always run in the same direction, and from the same pale of Sea.

The cooling effect of winter appears in the southern part of the North Sea, as well as on the coast of Norway, and the Bank water that enters in December, must be colder than the warm water of October and November, whether it originates from the northern or southern part of the North Sea.

As not a single fact indicates that the surface water along the S. E. coast of Norway can flow in, towards the Skagerrak, for any length of time, it will, most naturally, be assumed, that, the autumnal current system of the Skagerak pursues the same direction as it does during the remainder of the year.

Whence the herring comes, and where the various layers of water originate can only be discovered, when, on a sea going steamship, the conditions at sea can be investigated at all times of the year. Until then we deem it of no avail to put forward hypotheses, the correctness of which cannot be proved.

II.

The Christiania Fiord.

The hydrographical conditions of the Christiania Fiord are closely connected with those of the Skagerrak; the upper layers are constantly flowing out and in, partly on account of the tide, and, partly, from the winds.

The Fiord, however, retains a hydrographical character of its own, inasmuch as the inner part attains a great depth (up to over 200 metres), while, at the entrance, it is about 80 metres. The huge body of water below the depth of 80 metres is, therefore, quite shut off from direct communication with the deep water layers of the Skagerrak. As the salinity of the surface layers is much less than that of the deep, no great admixture takes place, and the changes of temperature are but slowly conducted to the deep downwards.

The water at the bottom of the Christiania Fiord may, thus, through a considerable space of time, retain an unaltered hydrographical character, by which the Fiord presents the greatest contrast to the sea just outside it, where the deep lying waters may be forced upwards, and carried away in a very short time, as we have previously shown.

The conditions in the depths of the Fiord show a much greater similarity, for instance, to those of the central part of the Skagerrak, where, all through the year, Atlantic water may be found at a depth of 50, to 100 metres, or more, with a temperature of 6—8°.

As yet, the Christiania Fjord has not been subjected to any close hydrographical examination. We regret to say that the observations which will be given in the following pages are not so complete as we should wish, for they could only be carried out, when occasion offered, at the same time as other investigations, and with certain biological ends in view. But they are, however, sufficient to throw a light upon a number of characteristic features of the hydrographical physiognomy of the Fiord.

Summer. We will commence with its condition during Summer. (Table III d).

The salinity of the surface is then very low; in the inner parts of the Fiord, that may be less than 20°/oo; the temperature is high, up to 20° or more. It is, however, only in the surface layers, that the temperature may exceed 15°. The salinity greatly increases downwards towards the bottom; thus at Drøbak at a depth of 60—100 metres, a salinity of 34°/oo may be met with, simultanously with a rapid decline of the temperature. Thus on the 17th of July 1897, off Hvitsteen, the temperature was:

at the	depth of	10	metres	11.°9
—	—»—	20	»	10.°2
—	—»—	30	»	7.°25
—	—»—	40	»	5.°78
—	—»—	50	»	5.°60
—	—»—	60	»	4.°91

The heat in the Summer finds no means of penetrating towards the bottom, as the uppermost, heated, layers do not mix with the bottom ones.

At the entrance of the Fiord, the higher temperatures, generally extend to a greater depth, 40—50 metres. In the one case this is, probably, due to the coastal currents of the Skagerrak, and in the other to the winds which can disturb the water more easily there and cause the upper layers to become mixed. The open, exterior basin of the Christiania Fiord, between Færder and Horten, forms, as regards the hydrography, a link between the coastal waters of the Skagerrak and those of the inner Fiord.

The heating of the upper layers thus extends to a greater depth than at Drøbak.

Hjort thus obtained on the 20th of August, 1894, the following temperatures from the centre of the Fiord (see [95] p. 75)

20	metres	16.°6
30	—	16.°0
40	—	14.°6
60	—	12.°0
80	—	7.°8

and Gran found, on the 6th—7th of August 1897,

		at Færder	at Vallø	at Drøbak (Hallangspollen) the 12th of August
0	metres	20.13	19.70	
10	—	16.74		18.9
20	—	14.32	14.10	12.2
40	—	12-63	10.70	8.8
60	—	9.54	7.84	6.3

The uppermost layers of the innermost part of the Fiord are replenished by the influx of water from the Skagerrak, and the water flows, daily, out and in. This may easily be observed, especially in the narrow sound at Drøbak, where the body of water is pressed together during its motion, and the velocity increased.

The currents appear to be principally regulated by the winds, and it may be clearly observed, how the warm surface layers, of little salinity, are wedged up in the innermost part of the Fiord after a southerly wind, while the northern winds drive them in an outward direction, thus allowing the Bank water to rise nearer to the surface in the inner portion of the fiord.

Little is known, however, to what the depths these daily currents may go. In one instance at Drøbak we have seen that the surface current was but 5 metres in depth; and, if this forms the rule, it may well be understood how, with reference to the hydrography, the inner basin of the Fiord can deviate so greatly from the outer portion.

The bottom layers, as will be noticed from the tables, are wonderfully cold, a minimum existing, during the Summer, at a depth of about 60 metres, and, below this, the temperature, throughout, is 5—6°, with a salinity of $34.5^0/_{00}$ or more. Further up the Fiord, the salinity of the bottom does not amount to $34^0/_{00}$; the temperature, however, being still lower.

During Summer, a fairly rich *Plankton* is frequently met with in the uppermost, heated, layers. Deeper down only a few crustaceans are found, chiefly, northern forms which keep to the cold water. Table 7, denotes the result of some quantitative plankton investigations, carried out with *Petersen's* self closing vertical net.

To assign the quantitative contents of the samples, we have adopted the weighing method, the samples preserved in spirits being filtered through a piece of silk-gauze, the surplus spirit being removed by means of filtering paper. A certain amount of spirit, however, does always remain which is retained by capillary attraction between the small organisms, and the greatest defect of the method is, therefore, that the various organisms do not retain each a proportionate amount. We consider the results, however, as being more reliable than other not too time-wasting methods, for instance, volumetric measurement.

The figures, given in the Table, indicate the weight of the quantity of Plankton obtained. Our net was of the same size and construction as that used by Petersen, and our results, may thus be directly compared with those derived from Petersen's researches in the Lim-Fiord [98].

The Table shows that the water, from the surface down to the depth of 20 metres, in August—September, contains many times greater an amount of Plankton than the deep lying layers.

At Aasgaardstrand, on the 30th of August, but 0.43 gr. was obtained from 20—50 metres, while 1.97 gr. was obtained, with the same net, from 40 metres to the surface, and in the deep water layers still less.

At Drøbak the difference is even more prominent, thus, according to the Table,

0— 20	metres	1.78	grammes
40— 60	»	0.18	»
80—100	»	0.03	»
120—140	»	0.05	»

The latter weights are so minute that they come under the defects of the method; such a quantity might be obtained in letting down the net, even if every attention was paid to lower the net with the opening up.

Thus the plankton vegetation is, practically, non-existent in the deep water layers of the inner part of the Fiord, except along the bottom. As to the distribution of the species, it will be observed from the Table, that the diatoms were found, exclusively, in the upper layers, while some of the peridiniaceæ also frequent a greater depth, though the majority of these, be mainly found near the surface.

Petersen's investigations prove, however [98], Tab. III, that diatoms may also be found in the deep; he having obtained considerable quantities of *Guinardia flaccida*, off Skagen, at depths of 40—90 fathoms.

It is possible in this case, that the currents off Skagen have drawn, towards the deep, layers which originally existed on the surface. Our Table also shews, that the diatoms may be found at greater depths. Further down the fiord, at Rauø, several species were found on the 16th of October, chiefly *Chætoceras contortum*, below the depth of 80 metres. Even in this case such may be ascribable to the currents, as the outer part of the fiord is closely connected with the coastal waters of the Skagerak.

Towards the end of the autumn, the quantity of plankton increased in the fiord; thus at Vrængen, on the 19th of September, 4.21 gr. was taken from the depth of 20 metres up to the surface, and at Drøbak on the 23rd, 3.92 gr. from 10—0 metres. This, for the coast of Norway, may be considered a very fair quantity, though, compared with the Lim Fiord and the Cattegat, quite insignificant. Thus, according to Petersen's investigations of the Lim Fiord, 27 gr. was obtained from depths of 5 fathoms to the surface; but as the sample was weighed in a fresh state, when saturated with salt water, (*vide* Petersen l. c. p. 8) this figure will need to be reduced to stand comparison.

Autumn.

The hydrographical features became somewhat changed during the autumn; the surface becoming cooler, while the warmth worked its way downwards. At that time, somewhat thick layers of warm water were found in the outer portion of the fiord, while, in the inner part, the warmth did not attain a great depth.

This will be observed, *inter alia,* from the hydrographical section, Vallø—Bygdø, during the latter half of September 1897, Tab. III, b, from which we give the temperature, and salinity, at the depth of 30 metres.

		Temperature		Salinity	
		0 metres	30 metres	0 metres	30 metres
Vallø		13.5	15.7	18.65	32.48
Horten		13.8	13.	20.94	31.67
Drøbak		13.5	11.1	20.34	32.43
Spro	inside Drøbak	13.78	6.4	19.37	32.26
Dyna		13.4	6.3	17.01	31.78

Thus, at Vallø, the temperature, at 30 metres depth, is higher than that of the surface; at Drøbak 2° less, and, inside, 7° less. This indicates, that the warm layers in the outer part of the fiord are not formed on the spot by mixing with the surface water, but come from without.

They, probably, are connected with the Bank water currents, which, according to the researches of Pettersson and Ekman, flow into the Skagerrak in September, and are of great depth.

In October (Tab. III c) the warm water layers are even thicker than in September; the hydrographical section, Fig. 8, denotes that, the water at Færder is of a temperature ot 12—13° to the very bottom. These hydrographical conditions are identical with those of the coastal waters of the Skagerrak during the Autumn.

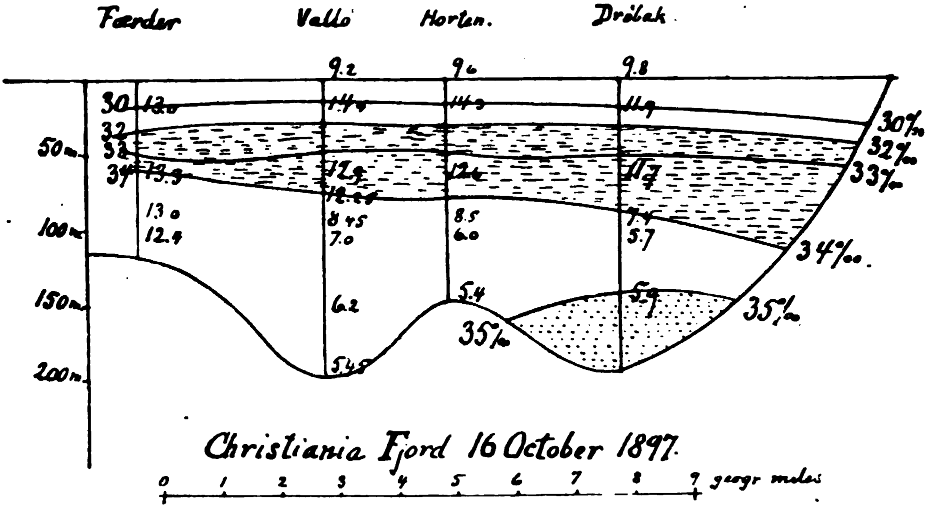

Fig. 8.

In the outer basin of the fiord, at Rauø and Bastø, the warm water does not go so deep, though it descends to nearly 80 metres below the surface. In the deep lies the cold bottom water, with a salinity of 34.5—35.0‰, which has remained stationary in the Fiord throughout the entire Summer.

In the upper layers, however, at a depth of 10—30 metres, a higher temperature may be found than at any other part beyond, or within the fiord (14.3—14.4°). If these warm layers originated from outside, they have, consequently, remained longer in the fiord than outside the entrance.

At Drøbak the upper layers are not even so warm as at Færder, their temperature does not rise to 12^0.

The boundary between the warm and cold water, the 10^0 curve, lies at about the same depth as in the outer part of the Fiord. In the deep, the water is remarkably salt, being $35\,^0/_{00}$ at the depth ot 200 metres; this being a salinity rarely experienced in the fiord. An influx of Atlantic water must, therefore, have made its way along the bottom from the outside, and then remained stationary in the deepest depressions of the fiord.

Fig. 9, gives a section ot the fiord in December 1896 (Tab. I d.).

Winter.

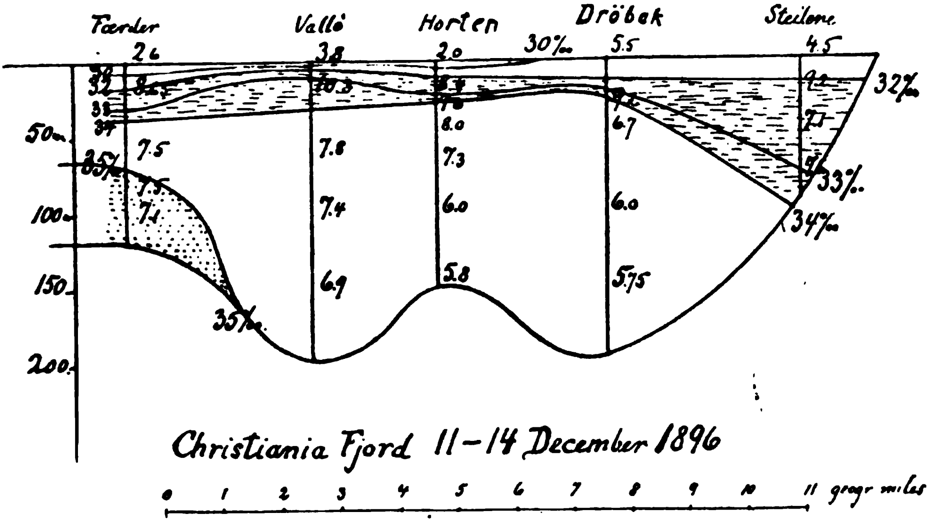

Fig. 9.

The conditions of the Skagerrak, as already mentioned, were, that year, most extraordinary, owing to the unusual deficiency of Bank-water, while the Atlantic water rose up high towards the surface, especially on the eastern side of the Skagerrak. This was also noticeabie at Færder (St. I), where Atlantic water was found at a depth of 80 metres. Atlantic water was, certainly, not to be met with in the upper part of the fiord, but the North Sea water (34—$35\,^0/_{00}$) rose to 30 metres from the surface, right up to Drøbak. Only at the innermost Station, «Steilene» (XX), was the salinity, down to the very bottom, lower than $34\,^0/_{00}$. The temperature was much lower than in the autumn; the maximum ($10.^03$) being then found at Vallø, at a depth of 20 metres.

It was remarkable that, at the two innermost Stations, Drøbak and Steilene, the temperature and salinity of the surface were higher than those of the outer Stations, higher even than the whole of the northern portion of the Skagerrak. This can only be explained by the surface water having been forced in an outward direction by the prevailing northerly winds, and replaced by warmer, and salter water from the deep.

The Plankton Table (1), shews the same; the two innermost Stations wanting the characteristic plankton which, otherwise, is spread over the entire surface of the Skagerak, and the Christiania Fiord. In the course of the winter, the upper layers gradually became cooler, both in the Skagerrak, and inside the fiord.

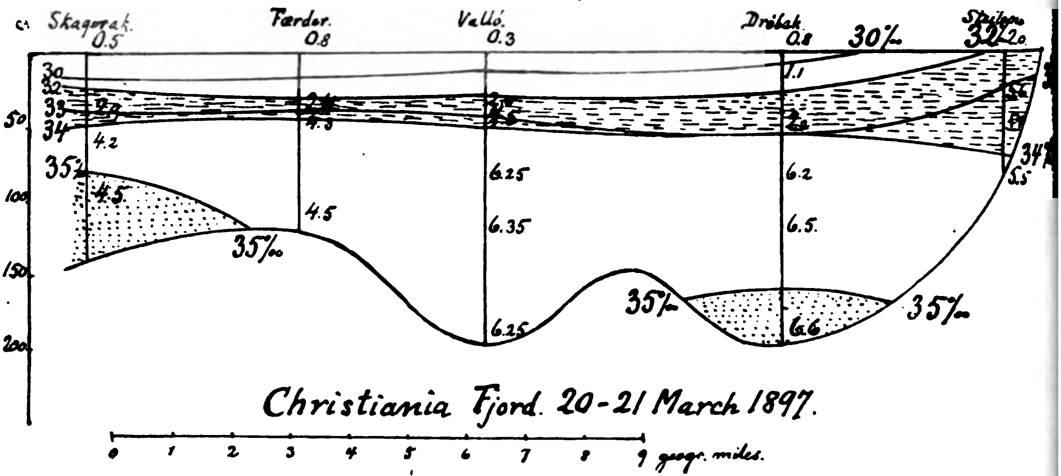

Fig. 10.

Fig. 10, shows a section of the fiord during the period, in which the sea is at its coldest, March, 1897.

Out in the Skagerrak, and at Færder, the temperature was low, throughout. Even the Atlantic water, which, in the Skagerrak, rose to 80 metres below the surface, was of a warmth of but 4.°5, and, at Færder, the North Sea water of a like temperature (4.°5), was found along the bottom.

In the outer basin of the fiord, at Vallø, the surface layers down to a depth of 40 metres, were somewhat colder than at the entrance; but, in the deep, water layers were found of a temperature above 6°, and these layers rose to, not quite 80 metres below the surface. They could not have been connected with the water layers of the same salinity (34.8—35.0) outside the entrance of the fiord, as the temperature was 2° higher. They had, thus, remained in the fiord since the autumn.

The cold surface layers, at Drøbak, lay 10 metres deeper than those at Vallø, but the bottom layers, were, still, a trifle warmer (6.°5 —6.°6). At the depth of 200 metres, a small body of water was found with a salinity exceeding 35‰, and, as the salinity is so great, it shews that this must have come in from outside. On the other hand it could not be related to the cold Atlantic water, which was found, at that time, out in the Skagerrak; it must, therefore, have entered at an earlier period, during the course of the autumn or winter.

In the innermost basin of the fiord, at Steilene, the salinity and temperature along the bottom, were lower than those of eqvivalent depths at Drøbak; but nevertheless, the salinity was exceptionally high compared with other observations in that part. During the summer and autumn, the salinity at Spro, and Steilene, never exceeded 33.0—33.5 ‰ at the depth of 70—80 meters; only at the bottom of the Bunde-Fiord was salter water met with. By that time, however, it had risen to 34.04 ‰, and 34.18 ‰, at depths of 70 and 85 metres.

If the salinities of the upper layers in the outer fiord be compared with those of the inner, one may perceive a condition which, probably, corresponds with the above.

Table III a, shews the following distribution of the salinity in March 1897.

	Vallø	*Drøbak*	*Steilene*
0 metres		29.66	32.03
10 »	29.93	30.30	32.33
20 »		31.69	32.69
25 »	31.42		
30 »		32.28	33.20
40 »	32.69		33.62
50 »	33.97	32.65	33.70

The farther the advancement up the fiord at that time of the year, the higher, therefore, will be the salinity of the upper layers down to a depth of 40—50 metres. In the summer and autumn, the salinity was invariably lowest in the inner part of the fiord, both on the surface and in the deep.

The temperature of the upper layers, also indicated a tendency to rise inside the fiord in the winter time, as will be seen from the Tables for March, 1897.

	Vallø	*Drøbak*	*Steilene*
0		0.8	1.95
10 metres	0.32	0.3	1.85
20 »		1.1	3.
25 »	0.35		
30 »		1.8	5.6
40 »	2.02		5.7

This could only be explained in one way viz., through the bottom layers of the upper fiord, having moved in an inward and upward direction, while the surface layers flowed outward.

The northerly winds having, probably, prevailed for a time, forced the surface water outwards, and the inflowing under currents ascended as a necessary compensation.

It is, also, commonly known, that the surface water of the Christiania Fiord is saltest during northerly winds, while southerly winds dam up the fresh water, as it were, in the inner portion of the fiord. It may therefore happen, that the fiord, during winter, is free from ice as long as the weather keeps cold, with northerly winds; but when milder weather sets in with southerly winds, it freezes, as the cold fresh water on the surface remains stationary, and the inflowing warm under currents are stopped.

The compensating currents which appear in the deep when the surface water flows in an outward direction, are of the greatest significance to the hydrographical conditions of the entire fiord, as new layers of water are brought in with these currents along the bottom of the fiord, where, otherwise, the water is apt to remain stationary.

The entrance to the fiord, as already said, is obstructed, on the bottom, by a ledge or bar rather more than 80 metres from the surface; the basins existing inside the fiord below this depth, can, therefore, only obtain fresh supplies, when bodies of water, of higher specific gravities than that of the bottom layers of the fiord, surmount the ledge.

We have, moreover, as mentioned previously, seen that, bodies of water — with the exception of the uppermost layers — have a great tendency towards remaining stationary in the fiord, even at depths, where there are no obstructions. The compensating currents are, probably, the only effective means of renewing the water at the bottom of the fiord.

In the Christiania Fiord the outward flowing currents of the surface seem to culminate in the winter. As yet, however, our materials are not sufficient to allow of any decisive conclusion being arrived at on this point, but there is another circumstance which points in that direction.

The course of the surface currents is, as a rule, dependent on those of the winds, thus, in the Christiania Fiord, the northerly winds produce an outward flow of the surface layers. Mohn's investigations, during the course of many years, ([98] pp. 15—16) indicate, that the northerly and north easterly winds prevail in the Christiania Fiord during the winter months (October—April), while south, and south westerly winds predominate in the summer (May—September).

During the winter, therefore, the surface currents chiefly run in an outward direction, and the compensating currents are drawn in along the bottom. In the summer, however, this will not so easily occur, as the surface layers more frequently flow in an inward than outward direction. We observed, too, that the saline contents of the surface, in summer' always became less the further one advances up the fiord; while the series of observations which, hitherto, have been obtained during the winter season, shew a higher salinity in the inner than in the outer part of the fiord.

Drammen Fiord.
Frier Fiord.

The Drammen Fiord, which was subjected to Hjort's researches in November 1898, has a deep basin, the water of which is still more isolated than the remainder of the water along the bottom of the Christiania Fiord. This fiord is separated from the Christiania Fiord at Svelvik, by a bar, which lies 6 metres below the surface.

The Tables of salinity and temperature (III e) shew, that the layers inside the Drammen Fiord are of quite a different character to those on the outside, at Filtvedt.

We give the following parallel:

	Salinity.		*Temperature.*	
	Drammen Fiord. 10/10 98.	Filtvedt. 11/10 98.	Drammen Fiord. 10/10 98.	Filtvedt. 11/10 98.
20 metres	25.03	32.40	9.65	13.2
30 »	28.41		4.8	
40 »	29.58	32.87	4.6	11.0
60 »	30.05	33.58	4.6	6.8
80 »	30.31		4.6	6.55
120 »	30.43	34.53	4.6	6.2

In the Drammen Fiord, the salinity, in November, was thus below 31°/₀₀ right to the bottom, and the temperature remained at 4.°6 from a depth of 40 metres downwards; while, outside, comparatively high temperatures were to be found to a great depth.

It was, however, still more remarkable that the water obtained with the water bottle from the deep layers, had a most incontestible odour of sulphuretted hydrogen, or «rotten egg gas» (H_2S), the bottom being in a decaying state from 20 m below the surface, and no organisms were procured there in a living condition.

Hjort found a similar condition obtaining in the Frier Fiord, inside Brevik, on the 30th of September. The salinity at the bottom was there much higher, slightly exceeding 34°/₀₀, while the temperature was 6.°4; but even there the bottom water smelt of sulphuretted hydrogen.

This fiord is obstructed by a bar, rising to 18 metres below the surface, and, in addition to this, it has even another feature similar to that of the Drammens Fiord, viz., that the salinity of the surface is very low, as an important river has its outlet in the fiord.

In December, the Frier Fiord was subjected to a close examination by our assistant, Mr. Schmidt Nielsen, who analysed the volumes of gas from the samples obtained at various depths both in the Frier Fiord, itself, and outside it at Brevik.

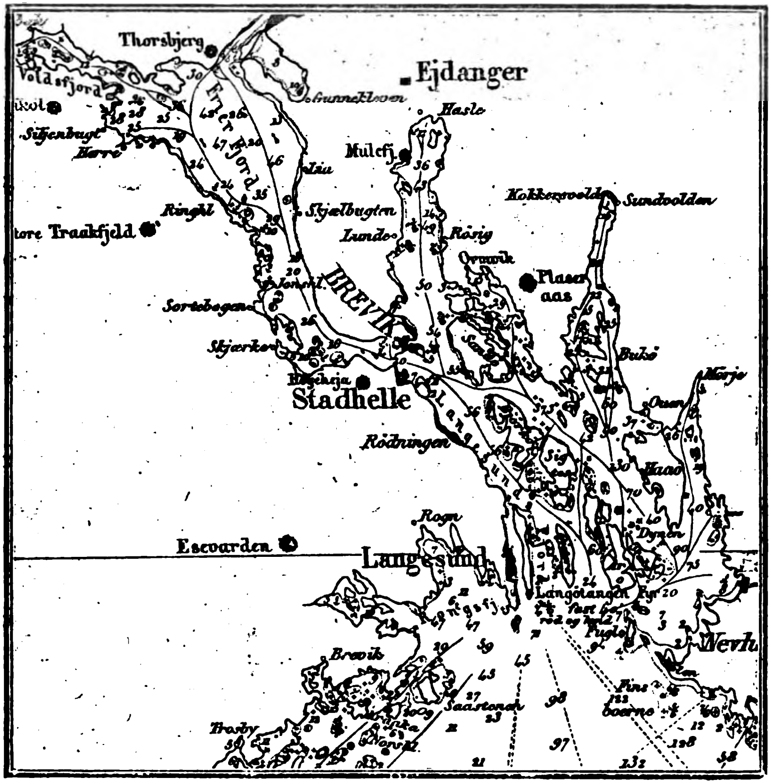

Fig 11. Brevik Fiord.

The results, being of great interest, are inserted in the following table, though these conditions will subsequently be reserved for more acurate study.

		Date.	0 m.	30 m.	60 m.	90 m.	100 m.
Salinity	Frier Fiord	30/9	5 .68	33 .65	33 .89	34 .07	
		6/12		33 .05	34 .03	34 .03	
»	Brevik Fiord	1/10	18 .33		33 .95		35 .55
		6/12			34 .56		34 .70
Temperature	Frier Fiord	30/9	$11^0.8$	$7^0.\ 4$	$6^0.\ 4$	$6^0.\ 4$	
		6/12		$9^0.\ 2$	$6^0.\ 0$	$6^0.\ 3$	
	Brevik Fiord	1/10	$12^0.6$		$12^0.\ 1$		$6^0.\ 9$
		6/12			$8^0.95$		$8^0.\ 1$
Nitrogen cc m. pr. l.	Frier Fiord	6/12		13 .0	19 .71		
	Brevik Fiord	6/12		13 .28	12 .96		
Oxygen. cc m. pr. l.	Frier Fiord	6/12		3 .7	2 .57		
	Brevik Fiord	6/12		6 .23	5 .67		
Oxygen °/₀ Gas vol. of	Frier Fiord	6/12		22 .16	11 .54		
	Brevik Fiord	6/12		31 .92	30 .43		
CO_2 cc m. pr. l.	Frier Fiord	6/12		48 .75		60 .23	
	Brevik Fiord	6/12			47 .87		49 .74

The water at the bottom of the Frier Fiord was thus very deficient in oxygen, but carbonic acid excessively plentiful. The quantity of sulphuretted hydrogen was not ascertained.

In April 1899, Hjort and Schmidt-Nielsen studied the hydrographical conditions at the bottom of the Christiania and Drammen Fiords, from Færder to the head of the fiords. The results will be found in the following Tables (page 45). The volume of Oxygen was normal at Færder; in the deep pool at Rauer it was somewhat below the normal, and still less at Rødtangen. In the Bunde Fiord less than 1 ccm. of oxygen *per* litre of sea water was met with, and, at the bottom of the Drammen Fjord, so little oxygen was found, both absolutely and relatively, that it need not be taken into account. The volume of Carbonic Acid was, on the other hand, very great at the bottom of the Bunde Fiord,

Conditions like those of the Drammen and the Frier Fiords, are, hitherto, only known to exist in one place, viz., in the Black Sea, where an abundance of sulphuretted hydrogen is to be found, in the deep, below 300 metres. The Black Sea was investigated by Russian expeditions in 1891—92 *(Spindler, Wrangell, Andrussof, Lebedintsef)*, and the results have been published in Petermanns Mitteilungen by *Wojeikow* [91], and refered to in Annalen d. Hydrographie, by Köppen [92], and Lebedintsef [93], and in *Geographisches Jahrbuch,* by Krümmel [93].

It appears from, these investigations, that the salinity of the Black Sea is exceedingly low on the surface (17—18⁰/oo), while in the deep regions it is greater; thus a salinity of 26⁰/oo was observed at a depth of 1185 fathoms, and, probably it was still greater along the bottom. The temperature scale for the summer, denoted a minimum (7.⁰2) at 53 metres depth, but, farther down, the temperature gradually rose, and slightly exceeded 9⁰. If the salinity be the same during the winter, the vertical circulation, which occurs through the cooling of the surface layers, would, according to Wojeikows calculations, reach down to a depth of 55 metres. These top layers may thus, possibly, absorb fresh air once a year from the atmosphere.

The vast bodies of water which lie below that depth, can, however, only be replenished by under currents flowing from the Bosporus.

Makarow has shewn, that such currents are to be found throughout

Locality	Date April, 1899	Depth from which the sample was taken. Metres	Temperature at that depth Celsius	Cl. per litre	Salt $^0/_{00}$	N ccm per litre	O ccm per litre	$\frac{100\,O}{N+O}$	CO_2 ccm per litre	Remarks
Færder	15	About 200	4.8	19.83	34.96	13.71	6.92	33.54		Near the bottom
Rauer	15	50	4.72	19.52	34.48	13.62	6.60	32.65		
	„	350	5.6	19.79	34.89	13.38	6.05	31.13	48.24	—„—
Rødtangen	15	120	6.1	19.76	34.84	13.25	5.89	30.77	46.82	—„—
Langaaren	21	160	5.7	19.05	33.63	13.84	5.84	29.67		—„—
Steilene	21	20	4.9	17.91	31.57	13.95	5.84	29.51	38.94	
Bunde Fjord	21	50	6.1	18.87	33.32	14.58	4.58	23.90		
	„	160	5.8	19.05	33.63	13.68	0.79	5.49	51.36	—„—
Drammen Fjord	15	25	4.55	16.18	28.69	14.71	3.80	20.48	45.08	
	„	120	4.55	17.16	30.38	14.60	0.13	0.88		—„—

the entire year; but as the Bosporus is very narrow, and extends to no great depth, but comparatively small quantities can find their way in.

Wojeikow has calculated, from Makarow's observations, that 3180 years would be required in order to replenish the water of the Black Sea.

In order to explain the conditions of the Black Sea, Andrussof set up the following hypothesis: In the pliocene period, the Black Sea formed a landlocked basin, containing, chiefly, brackish water, and a brackish water fauna on the bottom. When, however, the straights of the Bosporus subsequently opened, the sea water from the bottom of the Mediterranean forced its way in, and exterminated the brackish water organisms, which, on putrefying, produced a poisonous substance (H_2S) which prevented any new fauna entering from the Mediterranean. Meanwhile the decay continued, as a perpetual supply of organic sediments from the rivers, and the littoral fauna, poured in.

Several observations seem to comfirm the correctness of this interesting hypothesis; but the formation of sulphuretted hydrogen in the stagnant water layers, at the bottom of the Black Sea, may, probably, be explained, solely from those factors which are at work at the present time.

The conditions of the Norwegian fiords appear to be of a parallel kind. In them, too, may be found saltwater basins, whose only connection with the sea consists of shallow inlets, while much fresher water may be obtained on the surface than at the bottom, so that the vertical circulation in the winter is but of little consequence. The bottom layers, inside the fiord, are, therefore, more or less stationary, and the investigations made in the Drammen Fiord, during November 1898, denote, that the water, from the bottom, upwards, to 30 metres from the surface, had remained in the fiord, in any case from the preceding winter.

The layers must, necessarily, have crossed the bar, which lies but 6 metres below the surface, and outside, it is only during the winter that water of a corresponding temperature can be found so near the surface.

Pettersson and Ekman's investigation of the Swedish fiords shew that, the volume of oxygen declines in those bodies of water which, for some time, remain stationary in a fiord, while the carbonic acid increases. This change is owing to the change of substance in the organisms, and as animals were, exclusively, found at great depths, and no plants, the changes will always tend to the same result. If then the bodies of water remain stagnant for a very long period, they must become so deficient in oxygen that they are no longer capable of sustaining animal life. This has occurred in the Frier Fiord.

The high salinity (34.03‰) along the bottom of the Frier Fiord shows that, the salt water supply must, nevertheless, occur more frequently than that, for instance, of the Drammen Fiord, the salinity of which never exceeded 30.5‰.

The low amount of oxygen at the bottom, is bound to affect, not only the higher organisms, but also the bacteries and their change of substance. Putrefaction invariably occurs at the bottom of the sea, even if a great quantity of organic matter is consumed by higher animals. It depends, however, on the conditions of the surrounding medium, which bacteria shall attain the supremacy, and what products will arise from the decomposition. When oxygen is sufficiently represented, putrefaction takes place in a different way to that where oxygen is wanting.

In many instances it frequently happens that oxygen, freely supplied, causes a complete change of the organic substances, to carbonic acid and ammonia.

On the other hand, when oxygen is wanting, medium products are more easily formed, as leucin, tyrosin, while malodorous substances such as sulphuretted hydrogen are formed at the same time.

The fermentation arising from a small supply of oxygen constitutes a reductional process; besides the formation of H_2S, hydrogen is also formed, and this may, *in statu nascenti,* have a reductional effect on the sulphates of the sea water, so that sulphuretted hydrogen may, therefore, be a secondary product of the reduction.

Thus, possibly the formation of H_2S, along the bottom of our fiords, can be attributed solely to the stagnation of the bottom layers, by which any access of oxygen is precluded.

As is stated by Pettersson and Ekman, in respect to the Swedish fiords, this stagnation is caused by a bar, at the mouth of a fiord, which prevents a connection between the deep layers outside, and those within, while the low salinity of the surface only allows the vertical circulation during the winter to descend to a limited depth.

Of all the fiords which, hitherto, have been subjected to close observations, only the Drammen Fiord, and the Frier Fiord appear to have a «dead bottom» with any appreciable quantity of sulphuretted hydrogen; the remainder yielding a, more or less, plentiful fauna of oceanic deep water forms.

In those the fresh supply of water along the bottom is sufficient to support the respiration of the animals, and prevent anaerobiotic fermentation.

The results hitherto arrived at, will not suffice in determining the minimum quantity of oxygen required to prevent the formation of sulphuretted hydrogen on the bottom. In the Frier Fiord, at 60 metres depth, it amounted to 2.57 cm. pr. litre, but, at the bottom, the water was, probably, still more devoid of oxygen.

A very rapid change in the conditions of a fiord are not precluded; it being known, that deep water shrimps, *(Pandalus borealis)* were, at one time, caught in the Drammen Fiord at spots where now no living organisms exist below the depth of 20 metres. The conditions of the Black Sea may, in our opinion, be explained in a like manner, the character of its depths being in no way dependent on whether, in olden geological epochs, there was brackish or salt water at the bottom. The Christiania Fiord differs from the Drammen Fiord, and the Frier Fiord, in the fact that, the bar, being situated at a greater depth, allows of a more frequent renewal of the bottom layers. Moreover the access of fresh water to the surface is not so great as that of the other two fiords. Both these conditions probably contribute in causing the bottom water of the Christiania Fiord to maintain a comparatively less stationary position than those of the Drammen Fiord, and the Frier Fiord. We are, however, already acquainted with the fact that, even in the Christiania Fiord, large volumes of water remain throughout a great part of the year without renewal or blending. This is a most characteristic feature in the hydrography of the Christiania Fiord.

On the other hand, however, it is quite as characteristic that the surface water is invariably connected with the upper layers of the Skagerak. This may be observed not only from the hydrographical conditions, but also from the plankton of the surface layers.

Table 4 gives a general view of the vegetable plankton at Drøbak throughout the various seasons.

Firstly, it will be seen that, the various organisms have their maxima at certain times of the year; this is especially clear as regards the neritic diatoms. *Biddulphia aurita*, *Thalassiosira Nordenskiøldii* and *Th. gravida* vegetate, for instance, most exuberantly during the coldest season, in the month of March; *Chætoceras constrictum* and *Leptocylindrus* *danicus* rather later, in May; *Chætoceras curvisetum* in the summer; *Chætoceras didymum*, *Ch. Schüttii* in September; *Ch. contortum* in October; *Skeletonema costatum* in November.

The oceanic species vegetate more regularly all through the year (for instance *Thalassiothrix Frauenfeldii*), even though these have their decided maxima at fixed seasons. (*Coscinodiscus oculus iridis*, *Chætoceras decipiens*, *Thalassiothrix longissima* during the winter, *Rhizosolenia alata* during the summer). A comparison with Cleve's investigations of the Bohuslæn coast [97], shows that the same species are represented there, and have their maxima, and minima, practically at the same period.

The Christiania Fiord has thus no neritic plankton different from that on the coasts outside, or like that found in the Lim Fiord by Petersen [98]. Again it may be seen from the Table that the Plankton, may for a short period become very scarce. Such a gap in the Table, may, for instance, be found in the Table for December, 1896. On the first of December the plankton still retained considerable quantities of, for instance, *Thalassiothrix Frauenfeldii* Throughout the middle of the month it was absolutely wanting, and appears again on the 28th, in about the same quantity as before. Table 1, shews that the entire Skagerak, and the outer part of the fiord, just at that time, contained a rich plankton; it was only in the innermost part of the fiord that the plankton had, temporarily, disappeared. This coincides with the fact, that the surface water at that time was carried out of the fiord by the out flowing currents; the distribution of the temperature and salinity in the upper layers, moreover, also shew that this has been the case (see Fig. 9, Pag. 37). A similar gap will be observed in the Table during the first half of February 1897. In March, too, the hydrographical investigations (Fig. 10) shewed that there had been an outward flow of the surface currents. However they had not extended sufficiently deep to convey, with them, all the Plankton algæ (see Tab. 3). In March the Pelagic Diatoms had developed into enormous quantities, both outside and in the fiord.

The Plankton Investigations effected during the year 1898, also shewed, that the plankton in the Christiania Fiord is closely connected with that of the Skagerrak. Table 5, shews the vegetable plankton outside the fiord, at Hvaler, and Table 6 gives the results of some quantitative determinations, which were carried out, at the same time at Drøbak.

At Hvaler the plankton was poor in January and the first half of February; still it contained considerable quantities, chiefly of peridiniaceæ, and some oceanic diatoms. On the 19th February a rich diatomic plankton became developed, which during the following weeks, increased very considerably.

At Drøbak the Fiord was practically free of plankton throughout the entire month of February. The figures, denoting the weight of the Plankton, are so low, that they, for the most part, lie within the defective boundaries of the method.

But from the 23rd of February, until the 2nd. of March, the quantity of plankton in the upper layers, to a depth of 25 metres, had increased from 0.08 gr. to 3.49 gr., and it consisted of the same species as those which, from the middle of February, had grown luxuriantly outside the fiord. Even if these diatoms possess great powers of development, it is hardly possible that such great quantities could have sprung up on the spot.

Outside the fiord a gradual development took place, and it is more likely that outward currents kept the inner part of the fiord free of plankton throughout the entire month of February*), but that in the later days of the month a rich plankton was brought in by an inflowing current. All these conditions seem to shew, that the plankton of the Christiania Fiord originates, chiefly, from the Skagerak. This was also to be expected when the hydrographical conditions were taken into consideration. The conditions of life of the neritic forms, greatly depend upon whether the water, wherein they exist, comes in contact with the bottom; but in the Christiania Fiord the greatest part of the bottom is covered with more or less stationary layers, which during the summer, contain very little plankton (see Tab. 7).

This fiord is not, therefore, as is the Lim Fiord, a suitable centre for the development of neritic organisms. The oceanic plankton organisms are not adapted for life under changeable conditions, they cannot, therefore, remain in the upper layers of the fiord, but are frequently brought in from the Skagerrak.

In the deep layers, however, the oceanic organisms may subsist for a considerable period; thus several northern forms may be found in the depths of the fiord, viz., *Calanus finmarchicus*, and *Metridia longa*, which probably exist there throughout the entire year.

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*) Compare with this the results given in the preceding treatise, shewing that the pelagic fishes' eggs are driven out of the fiord.

But, quantitatively, they are of no great significance compared with the great number which invariably flow in from the Skagerrak with the surface currents, and which also, for a time, can continue their development inside the fiord.

We have already stated in the first part of this work, and in a former treatise, all we had to say of the Skagerrak Plankton up to the present. We believe that this plankton may be regarded as consisting, first of the neritic species, which annually are developed in the shallow water near the edge of the shore, and, secondly, of extraneous (»allogenetic«) organisms, which arrive, mainly, by the Jutland and Baltic currents.

The oceanic species, which keep throughout the year, in greater or less quantities, to the deep and central portions of the Skagerrak, are, probably, also of importance as food for the bottom fauna, and they may also, during some seasons of the year (i. e. winter and spring) give important contributions to the plankton of the surface layers, so that we, at such periods, find, in all the water layers, a uniform oceanic plankton, which, however, seldom lasts for any length of time.

Remarks on the Hydrographical Tables.

The Sea-water samples have been obtained with O. Pettersson's isolating water bottle, and the temperature of the water procured has been registered.

In some cases, the ascertainment of the temperature has been controlled by the reversible thermometer of Negretti & Zambra.

The chloric quantity of the sea-water has been determined by titration, which was effected by Dr. O. A. Heidenreich (Tabs I, II, III a, b, c, d, f, V) and Mr. Schmidt-Nielsen (Tab. III e, IV).

Remarks on the Plankton tables.

The occurrence of the various species is denoted in the following manner:

cc = very common
c = common
+ = rather common
r = rare

The samples mentioned in Tabs. 6 & 7 were captured with a quantitative net, Hensen's model, of gauze No 20, the upper opening being of an area of 0.09 square metres. The opening could be closed by means of C. G. Petersen's shutter.

The weighing process was carried out with preserved materials, the organisms being preserved in 70 per cent. of alcohol, and the alcohol removed, so far as possible, by means of filtering paper.

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HYDROGRAPHICAL TABLES

1. Sections of Skagerak and the Christiania Fjord, December 1896 (Hjort).

I. Sections of Skagerak and the Christiania Fjord.
December 1896. (Hjort).

a) Færder — Skagen.

No.	December 1896.		Weather	Locality	Soundings	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl. per litre	Salt per litre	Salt per mille	
1	11	12 noon.		59°1'N. *) 10°39'E.		0 m	2°. 6	15.37	27.82	27.28	*) Færder.
						10 —	3°. 6	16.10	29.15	28.55	
						15 —	6°. 8	17.63	31.88	31.15	
						20 —	8°.65	18.47	33.40	32.61	
						40 —	8°. 4	19.63	35.61	34.61	
						60 —	7°. 5	19.81	35.80	34.89	
						80 —	7°. 5	19.94	36.04	35.12	
						100 —	7°. 1	19.87	35.91	35.00	
						150 —	6°.55	19.84	35.86	34.95	
						200 —	6°. 4	19.89	35.96	35.04	
2	11	$2^{1}/_{4}$ p.m.		58°44' 10°37'		0 —	3°. 0	15.35	27.79	27.26	
						10 —	3°. 6	16.50	29.85	29.22	
						20 —	8°. 3	18.83	34.05	33.20	
						40 —	8°. 6	19.38	35.03	34.16	
						60 —	8°.05	19.60	35.43	34.53	
						80 —	7°. 6	19.81	35.84	34.89	
						100 —	7°. 3	19.89	35.96	35.04	
3	11	4 p.m.		58°33' 10°35'.5		0 —	3°. 4	14.80	26.83	26.32	
						12 —	5°. 9	18.10	32.74	31.98	
						20 —	7°. 8	18.75	33.91	33.09	
						40 —	9°. 4	19.46	35.16	34.30	
						60 —	8°. 1	19.53	35.30	34.40	
						80 —	7°. 4	19.84	35.86	34.96	
						115 —	7°.18	19.94	36.04	35.12	
						200 —	6°. 6	19.91	35.99	35.07	
4	11	$6^{1}/_{4}$ p.m.		58°14' 10°33'		0 —	3°. 4	13.41	24.34	23.92	
						10 —	7°. 2	18.01	32.58	31.85	
						20 —	8°.35	18.92	34.23	33.38	
						40 —	8°.55	19.30	34.89	34.04	
						60 —	8°. 9	19.53	35.30	34.40	
						80 —	7°.65	19.83	35.85	34.93	
						100 —	7°. 6	19.87	35.91	35.00	
5	11	$8^{1}/_{2}$ p.m.		57°59'.5 10°30'.5		0 —	3°. 4	14.57	26.42	25.92	
						10 —	6°. 3	17.44	31.56	30.84	
						20 —	8°. 6	18.92	34.23	33.38	
						40 —	9°. 1	19.40	35.06	34.20	
						60 —	8°. 2	19.71	35.62	34.71	
						80 —	7°.65	19.77	35.72	34.81	
						120 —	7°. 4	19.81	35.80	34.89	
6	11	11 p.m.		57°47' 10°32'		0 —	7°. 3	18.61	33.66	32.81	
						10 —	7°. 5	18.65	33.68	32.86	
						20 —	7°. 2	19.56	35.35	34.47	

No.	December 1896.		Weather	Locality	Soundings	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl. per litre	Salt per litre	Salt per mille	
6	11	11 p.m.		57°47'N. 10°32'E.		40 m	7°. 1	19.74	35 68	34.77	
						60 —	6°. 8	19 75	35 71	34 80	
						75 —	6°. 9	19.74	35.68	34.77	

b) Kattegat — Arendal.

7	12	2 a.m.		57°52.5' 11° 2'		0 m	3°. 3	12.60	22.88	22.51	
						10 —	3°. 3	12.73	23.11	22.74	
						20 —	7°. 9	17.49	31.64	30.91	
						30 —	7° 8	18.78	33.98	33.15	
						50 —	7°. 4	19 61	35.45	34.54	
						70 —	7°.25	19.75	35.71	34.80	
8	12			58° 6.5' 10°10'		0 —	6°. 7	15 01	27.19	26.67	
						10 —	7°. 3	16.67	30 18	29 53	
						20 —	6°. 7	18.07	32.68	31.93	
						40 —	8°. 0	19.09	34.51	33.66	
						60 —	8°. 1	19 30	34.89	34 02	
						80 —	8°. 3	19.49	35.23	34.34	
						100 —	7° 6	19.81	35.80	34.89	
						150 —	6°. 1	19.85	35.88	34.96	
9	12	7¼ a.m.		58°13.5' 9°44'		0 —	4° 9	16 44	29.76	29 14	
						10 —	5°. 1	16.56	29.97	29.34	
						20 —	6°. 3	18.51	33.47	32 67	
						30 —	7°. 6	18 90	34 18	33.35	
						50 —	8°. 8	19.46	35.16	34.28	
						70 —	7°.35	19 90	35.98	35.05	
						100 —	6°. 9	19.89	35.96	35.04	
						200 —	7°. 1	19.90	35.98	35.05	
10	12	9¼ a.m		58°20.5' 9°18'		0 —	5°. 2	18.24	32.99	32.21	
						10 —	5°. 9	18.24	32.99	32 21	
						20 —		18.52	33.49	32.68	
						30 —	8°. 5	19 23	34.76	33 89	
						50 —		19.74	35.68	34.77	
						100 —	7°. 2	19.87	35 91	35 00	
						200 —	6°.55	19.91	35.99	35 07	
						400 —	6°. 0	19.98	36.10	35.19	
11	12	11 a.m.		58°26' 8°57'		0 —	4°. 5	17.36	31.41	30.71	
						15 —	4°.85	17.54	31.72	31.01	
						30 —	5° 65	18.17	32.84	32 08	
						50 —	8°. 9	19.16	34.65	33.79	
						60 —	8°. 8	19.42	35.10	34.23	
						70 —	7°. 6	19.63	35.51	34.61	
						100 —	7°. 5	19.70	35.61	34.69	

No.	December 1896.		Weather	Locality	Soundings	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl. per litre	Salt per litre	Salt per mille	

c) Fredriksværn — Hvaler.

No.	Date	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl. per litre	Salt per litre	Salt per mille	Remarks
				58°58.5'N.		m.	° C.				
12	13	1/2 p.m.		10° 6'E.		0	2.3	15.52	28.12	27.56	
						15	2.8	15.82	26.64	28.07	
						30	5.9	18 26	33.03	32.25	
						50	8.4	19.46	35.16	34.30	
						70	8.15	19.55	35.32	34.45	
						100	7.5	19.62	35.47	34.56	
				58°55'							
13	13	2 1/4 p.m.		10° 7'		0	2.7	15.82	28.64	28 07	
						15	3.9	16.41	29.75	29.10	
						30	6.29	18.47	33.40	32.61	
						50	7.8	19.49	35.23	34.34	
						70	7.4	19.64	35 52	34.62	
						100	6.8	19.75	35.71	34.80	
				58°58.5'							
14	13			10°24.5'		0	3.3	15.77	28.57	27.97	
						15	3.4	16.33	29.57	28.93	
						30	6.7	18.58	33.63	32.74	
						50	7.9	19.49	35.23	34.34	
						70	7.0	19.74	35.68	34.77	
						100	7.4	19.65	35.53	34.63	
				59° 2.5'							
15	13			10°50'		0	2.5	15.62	28.30	27.74	
						10	6.0	17.25	31.22	30.54	
						15	8 35	18.31	33.12	32.33	
						20	9.7	18.67	33.78	32.94	
						30	8.8	19.26	34.81	33.95	
						40	8.35	19.53	35.30	34.40	
						50	7.8	19.58	35.40	34.51	
						70	7.7	19.55	35.32	34.45	

d) The Christianiafjord.

No.	Date	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl. per litre	Salt per litre	Salt per mille	Remarks
				59°15'							
16	11	10 3/4 a.m.		10°37'		0	3.8	16.67	30.18	29.53	**Valle.**
						10	9.6	18 82	34.04	33.20	
						20	10.3	19.06	34.46	33.63	
						40	8.4	19.47	35.19	34.32	
						60	7.8	19.72	35.65	34.71	
						80	7.5	19.73	35.66	34.75	
						100	7.4	19.76	35.72	34.81	
						150	6.9	19.86	35.89	34.97	
						300	5.2	19.82	35.85	34 92	
				59°23.5'							
17	14	8 a.m.		10°37.5'		0	3.5	16.70	30.23	29.57	
						10	5.1	17.20	31.12	30.43	
						20	8.8	18.64	33.71	32.90	
						30	9.0	19.41	35.08	34.21	
						40	7.9	19 52	35.29	34.40	
						50	7.8	19.64	35.52	34.62	
						70	7.4	19.68	35.58	34.68	

No.	December 1896.		Weather	Locality	Soundings	Depth from which sample at that depth	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl. per litre	Salt per litre	Salt per mille	
						m.	° C.				
18	14			59°26.7'N. 10°32.5'E.		0	2. 0	16.67	30.18	29.53	Horten.
						10	4. 0	16.96	30.69	30.02	
						15	7. 5	18.19	32.90	32.11	
						20	8. 4	18.46	33.37	32.58	
						30	9. 6	19.34	34 96	34.10	
						40	8. 6	19.47	35.19	34.32	
						50	8. 0	19.57	35.38	34.50	
						70	7. 3	19.71	35.62	34.71	
						100	6. 0	19.74	35.69	34.78	
						150	5. 8	19.71	35.62	34.71	
19	14			59°37' 10°38.5'		0	5. 5	17.62	31.87	31.14	Drøbak.
						10	6. 4	17.80	32.19	31.44	
						20	8. 9	18.66	33.76	32.93	
						30	9. 2	19.36	35.00	34.13	
						40	7. 6	19.40	35.06	34.20	
						50	6. 7	19 54	35.32	34.42	
						70	6. 2	19.52	35.29	34.40	
						100	6. 0	19.61	35.45	34.55	
						150	5.75	19.67	35.56	34.66	
20	14			59°47.5' 10°33'		0	4. 5	17.48	31.64	30.90	
						10	6. 2	17.48	31.64	30.90	
						20	9. 2	18.46	33.37	32.58	
						30	8. 8	18.51	33.47	32.67	
						40	8. 1	18.65	33.68	32.86	
						50	7. 1	18.61	33.66	32.81	
						75	7. 6	18.72	33.85	33.01	
						100	7. 6	18.76	33.93	33.11	

II. Sections off Langesund and Hvaler Autumn 1897. (Gran and Bie).

II. Sections off Langesund and Hvaler (Gran and Bie).

Station.	Autumn 1897.		Weather	Locality	Soundings	Depth from which the sample obtained	Temparature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl. per litre	Salt per litre	Salt per mille	

A. Section off Langesund 28—29th October 1897.

Station.	Date	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl. per litre	Salt per litre	Salt per mille	Remarks
	Octbr.			58°59′ N.		m.	° C.				½ mile SSO of
L_1	28	10 a. m.		9°46′.5 E.	135	0	8. 8	7.29			Langesund.
						20	12. 7	18.41	33.31	32.52	
						40	12. 6	19.35	34.98	34.12	
						60	12. 1	19.49	35.23	34.34	
						80	12. 0	19.59	35.42	34.53	
						120	12. 0	19.55	35.32	34.45	
				58°55′.5N.							4 miles SSO
L_2	29	9½ a. m.		9°49′ E.		0	7. 9				of Langesund.
						10	11.85	16.55	29.97	29.33	
						20	12. 0	18.13	32.80	32.03	
						40	12. 1				
						60	12. 4	19.32	34.92	34.06	
						80	12.35				
						120	12.45				
						200	12. 7				
				58°58′ N.							
L_3	29	3 p. m.		9°51′ E.		0	8. 8	12.62	22.92	22.55	
						10	11. 8	17.35	31.40	30.70	
						20	12. 4	18.41	32.31	32.52	
						40	12. 0	19.07	34.48	33.64	
						60	11.95	19.35	34.98	34.12	
						80	11. 5				
						120	11.35				
						200	11. 4				
						250	11. 9	19.42	35.10	34.20	

B. Section off Langesund 5—6th November 1897.

Station.	Date	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl. per litre	Salt per litre	Salt per mille	Remarks
	Novbr.			58°59′ N.							
L_1	6			9°46′.5E.	135	0	6.96	9.72	17.59	16.37	
						10	9. 9	14.87	26.96	26.44	
						20	12. 2	17.81	32.24	31.50	
						40	12.12	19.14	34.60	33.76	
						60	11. 5	19.63	35.51	34.61	
						80	10.10	19.83	35 85	34.93	
						100	8. 3				
						120	7. 5				
				58°55′.5N.							
L_2	5			9°49′ E.		0	7. 4	12.97	23.55	23.15	
						20	11. 7	17.49	31.66	30.95	
						80	8. 5	19.91	35.99	35.07	
						100	7. 2				
				58°53′ N.							
L_3	5	2 p. m.		9°51′ E.		0	8.26	13.18	23.92	23.52	
						10	10. 6	15.22	27.60	27.05	
						20	10.48	17.35	31.40	30.70	
						40	11.92	19.07	34.48	33.64	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Dato	Hour						Cl per litre	Salt per litre	Salt per mille	
						m.	° C.				
L_3	Novbr. 5	2 p. m.		58°53′ N. 9°51′. E.		60	11.14	19.63	35.51	34.61	
						80	8. 5	19.88	35.93	35.01	
						100	7. 4	19.98	36.10	35.19	
						120	7. 2				
						150	7.08	20.11	36.34	35.43	
						200	6.32	20.11	36.34	35.43	
						250	5. 9	20.11	36.34	35.43	

C. Section off Langesund 10—11th November 1897.

Station	Dato	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl per litre	Salt per litre	Salt per mille	Remarks
	Novbr.					Meter					
L_2	10	1 p. m.		58°55′.5N. 9°49′ E		0	5. 6	11.87	21.57	21.24	
						10	9. 0	14.54	26.37	25.87	
						20	12. 0	18.10	32.74	31.98	
						40	12. 0	19.22	34.75	33.88	
						60	9. 5	19.96	36.07	35.15	
						80	7. 9	20.00	36.14	35.21	
						120	7. 2	20.00	36.14	35.21	
						150	7. 0	20.10	36.32	35.37	
						200	6. 2	20.03	36.19	35.26	
L_4	11	1 p. m.		58°50′ N. 9°54′ E.		0	7. 7	13.49	24.48	24.06	
						10	11. 5	18.07	32.69	31.92	
						20	11. 4	18.48	33.43	32.64	
						40	11. 2	19.66	35.54	34.64	
						60	9. 0	19.87	35.91	35.00	
						80	7. 6	19.93	36.03	35.10	
						120	7. 2	19.93	36.03	35.10	
						200	7. 0				
						280	6. 8				

D. Observations at Langesund 13—24th November 1897.

Station	Dato	Hour	Weather	Locality	Soundings	Depth	Temperature	Cl per litre	Salt per litre	Salt per mille	Remarks
	Novbr. 13					0	11. 1	16.95	30.68	30.02	4 miles S of Langesund.
	15					0	9. 0	14.54	26.37	25.87	1 mile S of L.
	17					0	7. 9	14.31	25.96	25.48	8 miles S of L.
L_2	18	2 p. m.		58°55′ N. 9°49′ E.		0	7.85	13.76	24.96	24.52	
						10	8. 3	14.17	25.71	25 24	
						20	10. 7	17.76	32.15	31.41	
						40	10. 8	19.02	34.39	33 55	
						60	10. 6	19.70	35.61	34.69	
						80	10. 1	19.80	35.79	34.88	
						120	9. 2	19.87	35.91	35.00	
						200	7. 6	20.00	36.14	35.21	
	20					0	9. 4	13.70	24.86	24.42	Langesund E of the lighthouse.
L_4	22	12 noon.		58°50′ N. 9°54′ E.		0	8. 9	16.34	29.54	28.96	
						10	8. 6	16.85	30.51	29.85	
						20	8. 4	18.41	33.31	32.52	
						40	9. 3	19.66	35.54	34.64	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
				58°50′ N.		m.	° C.				
L₄	22	12 noon.		9°54′ E.		60	9. 4	19.73	35.60	34.75	
						80	9.35	19.80	35.79	34.88	
						120	9. 3	19.83	35.85	34.93	
						200	9. 3	19.80	35 79	34.88	
						250	9. 4	19 83	35.85	34.93	
	24					0	8. 2	17.96	32.49	31.74	8 miles. } S. of
						0	7. 7	16.88	30.56	29.90	1 mile } L.

E. Section off Langesund 25th November 1897.

	Novbr.			58°59′ N.							
L₁	25	9 a. m.		9°46′.5E	135	0	7. 0	15.80	28.68	28.05	
						10	7. 7	17.76	32.15	31.41	
						20	8. 1	18.10	32.74	31.98	
						40	9. 5	19.12	34.57	33.71	
						80	9. 5	19.66	35.54	34.64	
						120	7. 8	20.00	36.14	35.21	
				58°55′.5N.							
L₂	25	10½ a. m.		9°49′ E.		0	6. 6	17.29	31.29	30.59	
						10	7.45	17.97	32.51	31.75	
						20	9. 2	18.88	34.15	33.29	
						40	9.35	19.12	34.57	33.71	
						60	9. 3	19 21	34.74	33.87	
						80	9. 3	19.39	35.04	34.18	
						200	9. 2	19.46	35.16	34.30	
				58°53′ N.							
L₃	25	1½ p. m.		9°51′ E.		0	6. 7	17.56	31.79	31.07	
						10	7. 6	17.97	32.51	31.75	
						20	7. 8	18.14	32.81	32.05	
						40	9. 1	19.29	34.87	34.01	
						60	9. 4	19.46	35.16	34.30	
						80	9. 4	19.46	35.16	34.30	
						120	9. 2	19.40	35.06	34.20	
						200	9.25	19.50	35.25	34.36	
						250	9. 1	19.50	35.25	34.36	

F. Observations at Langesund 30th November—4th December 1897.

	Novbr.			58°53′ N.							
L₃	30	3 p. m.		9°51′ E.		0	6. 7	17.99	32.54	31.78	
						10	7. 2	18.13	32.80	32.03	
						20	8. 1	18.59	33.63	32.82	
						40	8. 5	18.98	34.24	33.40	
						60	8. 6	19.32	34.92	34.06	
	Decbr.			58°59′ N.							
L₁	4	10 a. m.		9°46′.5E.		0	4. 8	16.40	29.70	29.07	
						10	6. 5	18.06	32.67	31.91	
						20	6. 6	18 09	32.72	31.96	
						30	7. 6	18.43	33.34	32.55	
						40	9. 4	19.29	34.87	34 01	
						60	8. 7	19.85	35.88	34.96	
						80	8. 6	19.89	35.96	35 04	
						120	8. 0	20.05	36.23	35.29	

Station	Autumn 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
						m.	° C.				
L₂	Decbr. 4	2½ p. m.		58°55'.5N. 9°49' E.		0	6. 0	18.06	32.67	31.91	
						10	6. 5	18 06	32.67	31.91	
						20	6. 3	18.13	32.80	32.03	
						30	7.45	18.36	33.22	32.43	
						40	8. 8	18.96	34 29	33.44	
						60	8. 9	19.62	35.47	34.56	
						80	8. 7	20.02	36.18	35.25	
L₃	4	12 noon.		58°53' N. 9°51' E.		0	6. 1	18.06	32.67	31.91	
						10	6. 3	18.06	32.67	31.91	
						20	6. 5	18.09	32.72	31.96	
						30	7. 0	18.16	32.86	32.08	
						40	8. 8	19.12	34.57	33.71	

G. Observations at Hvaler 30th November 97.

H₁	Novbr. 30			58°59'.8N. 10°59' E.		0	5. 5	15.70	28.45	27.88	
						9	9. 0	19 06	34.46	33.63	
						19	9. 2	19.14	34.60	33.76	
						28	9. 2	19.16	34.65	33.79	
						38	9. 2	19.29	34.87	34.01	
						56	9. 2	19 39	35.04	34.18	
						75	9. 1	19.59	35.42	34.58	
						94	8. 8	19.79	35 78	34.86	
						113	8. 5	19.81	35.80	34.89	
H₂	30			59° 0'.3N. 10°55' E.		113	8. 6	19.79	35.78	34.86	
						188	8. 0	19.92	36.01	35.09	
H₃	30			58° 0'.7N. 10°47' E		0	7. 0	17.32	31.35	30 64	
						9	7. 0	17.33	31.36	30.66	
						19	8. 8	18.72	33.85	33.04	
						28	9. 0	19.16	34 65	33.79	
						38	8. 9	19.29	34.87	34.01	
						56	9. 3	19.46	35.16	34.30	
						75	9. 0	19.79	35.78	34.86	
						94	9. 0	19.82	35.85	34.92	
						113	8. 8	19.92	36.01	35.09	
						141	8. 6	19.92	36.01	35.09	
						188	8. 5	19.95	36.05	35.13	
H₄	30			58°57'.4 10°34'		0	6. 9	17.66	31.97	31.24	
						9	7. 2				
						19	8. 0	18.22	32 96	32.19	
						28	8. 9	18 99	34.34	33.48	
						38	9. 0	19.16	34.65	33.79	
						56	9. 3	19.27	34.83	33.97	
						75	9. 1	19.51	35.28	34.38	
						94	9. 3	19.79	35.78	34.86	
						113	9. 0	19.92	36.01	35.09	
						188	8. 6	20.09	36.30	35.36	

H. Observations at Hvaler, November 1898.

Station	November 1898		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
				58°57′.8N		m.	° C.				
H_1	7			10°59′ E		0	6. 7	9.06			
						5	9. 0	14.05	25.49	25.03	
						10	9. 1	15.23	27.61	27.07	
						20	9,85	16.80	30.42	29.77	
						30	10. 0	17.47	31.62	30.91	
						40	10. 2	—	—	—	
						50	10. 2	18.41	33.31	32.52	
						60	10.28	—			
						80	10. 2	18.65	33.74	32.92	
						100	9. 0	19.48	35.21	34.33	

III. Observations in the Christiania Fjord.

a) Skagerak—Christiania, March 1897.
b) Vallø—Bygdø, September 1897.
c) Færder -Drøbak, October 1897.
d) Observations in the inner Christianifjord, Summer 1897.
e) Sections of the Christianiafjord, Autumn 1898.
f) Observations at Drøbak, February—April 1898.

III. Observations in the Christiania Fjord.

a) Section Skagerak—Christiania March 1897. (Hjort).

Station	1897 Date	 Hour	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents Cl per litre	 Salt per litre	 Salt per mille	Remarks
	March				m.	° C.				
21	20		Skagerak		0	0. 5	14.07	25.53	25.06	
					10	1.12	16.65	30.15	29.49	
					20	1.30	17.61	31.87	31.12	
					40	2.85	18.83	34.05	33.20	
					60	4.20	19.75	35.71	34.80	
					80	4. 4	19.90	35.98	35.05	
					100	4. 5	19.90	35.98	35.05	
22	20		Færder		0	0. 8	14.07	25.53	25.06	
					40	2. 4	18.57	33.60	32.73	
					50	4. 3	19.39	35.04	34.18	
					80	4.32	19.75	35.71	34.80	
					120	4. 5	19.82	35.85	34.92	
23	20		Valle		10	0.32	16.91	30.61	29.93	
					25	0.35	17.76	32.15	31.42	
					40	2.02	18.53	33.50	32.69	
					50	4.55	19.27	34.83	33.97	
					80	6.25	19.78	35.75	34.83	
					120	6.35	19.75	35.71	34.80	
					200	6.25	19.86	35.89	34.97	
24	20		Drøbak		0	0. 8	16.75	30.32	29.66	
					10	0. 3	17.13	30.98	30.30	
					20	1. 1	17.94	32.44	31.69	
					30	1. 8	18.28	33.07	32.28	
					50	2. 2	18.50	33.45	32.65	
					60	4.78	19.38	35.03	34.16	
					80	6. 2	19.68	35.58	34.68	
					120	6.53	19.86	35.89	34.97	
					200	6. 6	19.90	35.98	35.04	
25	21		Steilene		0	1.95	18.16	32.80	32.03	
					10	1.85	18.31	33.12	32.33	
					20	3. 0	18.53	33.50	32.69	
					30	5. 6	18.83	34.05	33.20	
					40	5. 7	19.05	34.44	33.62	
					50	5. 7	19.11	34.55	33.70	
					70	5. 4	19.31	34.91	34.04	
					85	5. 5	19.39	35.04	34.18	

b) Section of the Christianiafjord September 1897. (Hjort).

Station	Date	Hour	Locality	Soundings	Depth	Temperature	Cl per litre	Salt per litre	Salt per mille	Remarks
26	Septbr. 21		59°14'8.N. 10°37' E.		0	13. 5	10.40	18.90	18.65	Valle-Rauer
					30	15. 7	18.39	33.27	32.48	
					50	13. 2	18.77	33.94	33.12	
					75	8. 1	19.17	34.67	33.81	
					100	5. 8	19.55	35.32	34.45	
					150	5. 2	19.72	35.65	34.76	
					200	5. 1	19.75	35.71	34.80	
					250	5. 0	19.75	35.71	34.80	

Station	1897		Locality	Soundings		Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
27	Septbr. 22		59°14′.8N. 10°37′ E.			0	13. 8	11.70	21.26	20.94	Horten
						15	15. 0	16.59	30.04	29.40	
						30	13. 0	17.92	32.42	31.67	
						75	7. 5	19.07	34.48	33.64	
28	23		59°37′. N. 10°38′.5E.			0	13. 5	11.36	20 64	20.84	Drøbak
						5	14. 7	15.50	28.09	27.53	
						10	13. 0	16.18	29.30	28.69	
						20	11. 0	17.54	31.75	31.04	
						30	11. 1	18.36	33.22	32.43	
						40	9. 9	18.46	33.40	32.60	
						50	8 7	18.70	33.82	33.00	
						60	8. 2	18.84	34.06	33.24	
						80	5. 7	19.31	34.91	34.04	
						100	5 65	19.58	35.40	34.51	
						150	5.75	19.82	35.85	34 92	
						200	5. 8	19.82	35.85	34.92	
29	23		Spro			0	13.78	10.81	19.64	19.37	
						10	13. 9	15.13	27.43	26 90	
						20	10. 0	17.27	31.26	30 56	
						30	6. 4	18.26	33.03	32.26	
						40	5. 5	18.73	33.87	33.05	
						60	5. 3	18.90	34.15	33.35	
						80	5. 2	18.95	34.27	33.43	
30	23		Dyna			0	13. 4	9.52	17.24	17.01	
						5	14. 2	10.81	19.64	19 37	
						20	9. 4	17.07	30.99	30.22	
						30	6. 3	17.99	32.54	31.78	

c) Section of the Christianiafjord, October 1897. (Hjort).

31	Octbr. 16		59° 1′ N. 10°37′.5E.			10	12. 0	15 78	28.59	28.02	Færder
						20	13. 0	17.49	31.66	30.95	
						30	12. 3	18.02	32.60	31.84	
						40	12. 2	18 34	33.18	32.40	
						65	13. 3	19 42	35.10	34.23	
						85	13. 0	19.56	35.35	34.47	
						100	12. 4	19.67	35.56	34.66	
32	16		59°13′.5N. 10°40′ E.			0	9. 2	8.84	14.39	14.24	Rauø
						10	12. 4	15.57	28.21	27.65	
						20	14.42	17 67	31.99	31.26	
						30	14.30	18.34	33.18	32.40	
						40	13. 6	18.58	33.61	32.81	
						60	12. 9				
						75	12.25	19.28	34.85	33.99	
						80	8.45	19.35	34.98	34.12	
						100	7. 0	19.63	35.51	34.61	
						150	6. 2	19.81	35.80	34.89	
						200	5.45	19.85	35.88	34.96	

Station	1897		Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour					Cl per litre	Salt per litre	Salt per mille	
	Octbr.				m.	° C.				
33	16		Bastø.		0	9. 6	9.87	17.84	17.61	
					20	14. 3	17.56	31.79	31.07	
					40	13. 7	18.41	33.31	32.52	
					60	12. 6	19.04	34.42	33.58	
					80	8. 5	19.28	34.85	33.99	
					100	6. 0	19.60	35.42	34.53	
					150	5. 4	19.70	35.61	34.69	
34	16		Drøbak.		0	9. 8	11.43	20.77	20.45	
					20	11. 9	17.18	31.09	30.42	
					40	11. 9	18.37	33.23	32.45	
					60	11. 7	19.11	34.55	33.70	
					80	7. 4	19.11	34.55	33.70	
					100	5. 7	19.63	35.51	34.61	
					150	5. 9	19.97	36.08	35.16	

d) Observations in the inner Christianiafjord, Summer 1897.

	July 17		Hvitsten		0	18. 0	12.17	22.11	21.76	
					10	11. 9	17.03	30.82	30.15	
					20	10. 2	17.88	32.36	31.61	
					30	7.25	18.02	32.60	31.84	
					40	5.78	18.53	33.52	32.72	
					50	5.60	18.63	33.70	32.89	
					60	4.91	19.26	34.81	33.95	
					100	5.70	19.72	35.65	34.76	
					200	5.15	19.72	35.65	34.76	
	Aug. 11		Sandspollen.		7	19.25	12.99	23.58	23.18	
					10	11.70	16.48	29.84	29.21	
	12				0	19. 8	19.21	22.18	21.83	
					5	19. 9	12.24	22.23	21.88	
					7	19. 7	12.41	22.54	22.18	
					10	19. 4	12.62	22.92	22.52	
	12		Inner part of Hallangspollen.		10	18. 0	13.46	24.43	24.01	
	12		Hallangspollen.		10	18. 9	13.02	23.64	23.24	
					15	17. 8	13.50	24.50	24.08	
					20	12. 2	16.01	29.01	28.41	
					24	9. 0	17.51	31.69	30.98	
					30	8. 8	17.58	31.82	31.11	
					40	8. 8	17.65	31.95	31.23	
					50	6.65	18.53	33.52	32.72	
					60	6. 3	18.67	33.77	32.96	
	13		Off the Sætrepollen		0	20. 0				
					38	5.45	18.70	33.82	33.00	
	13		Kaholmen.		41	5. 7	18.77	33.94	33.12	

Station	Aug. 1897		Locality		Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
						m.	° C.				
	14					1	19.25	8.23	14.89	14.72	Borsen
						7	20. 8	12 44	22.59	22.23	
						10	16. 7	13 26	24.07	23.66	
						15	7. 5	17.07	·0.99	30.22	
						24	6. 2	18.53	33.52	32.72	
	14					6	21. 0	11.90	21.62	21.29	Næsøen.
	14					7	19. 4	12.48	22.66	22.30	Sandviken.
						10	17. 1	13.02	23.64	23.24	
	15					0	19.75	11.97	21.75	21.42	Sandviken.
						7	19. 2	12.65	22.97	22.60	
						10	18. 3	13.46	24.43	24.01	
						20	7. 4	17.27	31.26	30.56	
						30	5. 6	18.02	32.60	31.84	
						40	5. 7	18 70	33.82	33.00	
						50	6. 1	18 90	34.18	33.35	
						60	6. 0	18.90	34.18	33.35	
	26	10 a. m.			120	0	18. 1	11.63	21.73	20.81	Steilene.
						10	18. 0	12.17	22.11	21.76	
						20	8.85	17 00	30.77	30 10	
						40	5. 3	18.77	33.94	33.12	
						60	5. 4	18.77	33.94	33.12	
						80	5.45	18.77	33.94	33.12	
	26	11.30 a. m.			80	0	18. 2	11.76	21.37	21.05	Spro.
						10	18.15	12.04	21.87	21.54	
						20	8. 8	17.20	31.13	30.45	
						30	5. 7	18.29	33.09	32.31	
						40	5. 5	18.70	33.82	33.00	
						60	6. 1	18.78	33.96	33.14	
	26	1 p. m.			65	0	18. 2	11.56	21.01	20.69	Næsodden.
						10	18 2	12.34	22.41	22.06	
						20	8. 4	17.34	31.38	30.68	
						30	5. 2	18.43	33 34	32 55	
						40	5. 4	18.87	34.13	33.27	
						65	5. 8	18.90	34.18	33.35	
	26	2.30 p. m.			142	0	19. 1	11.76	21.37	21.05	Bundefjord.
						10	18. 2	12 38	22.48	22.13	
						20	8. 2	17.00	30.77	30.10	
						40	4. 9	18.36	33.22	32.43	
						60	4. 1	17.78	32.18	31.45	
						80	4.95	18.29	33.09	32.31	
						100	5.35	18.70	33.82	33.00	
						142	5. 5	18.77	33.94	33.12	
	Septbr. 6					0	16.58	8.91	16.14	15.94	Drøbak.
						5	15. 5	13.26	24.07	23.66	
						10	15. 0	15.50	28.09	27.53	

Station	September 1897		Locality	Soundings		Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
	Septbr					m.	° C.				
	6					20	14. 0	16.39	29.68	29.05	Drøbak.
						30	12. 2	17.27	31.26	30.56	
						40	11. 2	17.78	32.18	31.45	
						60	9. 5	18.26	33.03	32.26	
						80	8. 8	18.70	33.82	33.00	
						100	7. 2	19.38	35.03	34.16	
						120	6. 3	19.65	35.53	34.63	
						150	6. 0	19.72	35.65	34.76	
						180	6. 0	19.82	35.82	34.92	
	10					0	15. 2	9.62	17.41	17.18	Bundefjord.
						10	15. 5	14.21	25.78	25.31	
						20	9. 0	17.00	30.77	30.10	
						40	5. 5	18.84	34.06	33.24	
						60	6. 0	19.11	34.55	33.70	
						80	6. 0	19.24	34.77	33.91	
						100		19.38	35.03	34.16	
						150	6. 0	19.31	34.91	34.04	
	14					0	16. 2	10.74	19.51	19.25	Næsodtangen.
						10	13. 8	15.37	27.87	27.30	
						20	9. 0	17.48	31.64	30.93	
						40	6. 2	18.80	33.99	33.17	
						60	6. 0	19.04	34.42	33.58	
						80	6. 0	19.11	34.55	33.70	
	14					0	16. 1	10.88	19.77	19.49	Langaaren
						10	14. 3	14.89	27.00	26.48	
						20	11. 5	17.41	31.51	30.81	
						40	6. 2	18.84	34.06	33.24	
						60	5. 8	18.90	34.18	33.35	
						80	5. 5	18.97	34.31	33.46	
						100	5. 5	19.04	34.42	33.58	
						140	5. 3	19.07	34.48	33.64	
	19					0	14. 5	14.69	26.63	26.13	Vrængen.
						13	15. 0	15.98	28.95	28.36	
						33	14. 4	18.56	33.58	32.77	E of Vræng.
						10	15. 0	15.03	27.25	26.72	W. of Vræng.
						20	15. 2	17.68	32.00	31.28	
	20					0	14. 5	14.48	26.26	25.77	Off Uleholmen
						9	15. 0	15.78	28.59	28.02	
						18	15. 5	17.20	31.13	30.45	
						27	15. 8	17.88	32.18	31.45	

Station	September 1898		Locality	Soundings		Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	

e) Section of the Christianiafjord, Autumn 1898. (Hjort and Schmidt-Nielsen).

						m.	° C,				
1						0	15.55	11.91	21.64	21.31	Lysaker.
						5	15. 8	13 23	24 01	23 60	
						10	15. 1	13.66	24.79	24.35	
						20	12 9	15.55	28.18	27.61	
						25	8.25	17.37	31 44	30.73	
						30	6. 9	18 19	32.90	32.13	
						40	6. 5	18.62	33.68	32.87	
						60	6. 3	18.83	34.05	33 20	
2						0	14. 8	13.06	23 71	23 31	Filtvedt.
						10	14. 6	13 34	24.21	23.80	
						20	10. 5	17 41	31.51	30 81	
						40	10. 2	18.19	32.90	32.13	
						60	7. 6	18.76	33.92	33 10	
						100	6.15	19 58	35 40	34 51	
						200	6.15	19.80	35.79	34.88	
8	3	p. m.	59° 0′.5 N. 10°55′ E.			0	16. 0	8 70			
						10	14.45	17.41	31.51	30 81	
						20	14.05	18.22	32 96	32.19	
						40	13 7	18.69	33 80	32.99	
						60	13. 1	18 90	34.18	33.35	
						8	10 15	19.15	34.62	33.78	
						120	7. 3	19 73	35 66	34.75	
						200	7. 1	19.87	35.91	35.00	
12			59°12′ N. 10°36′.7 E.	75		0	14.85	14.41	26.14	25.66	
						10	14.65	16.16	29.26	28 65	
						20	13. 9	16 94	30.67	30.00	
						40	13.85	18.33	33 16	32.38	
						60	12.95	18.76	33.92	33.10	
						75	8.35	19.08	34.51	33.65	
16			58°53′ N. 10°11′ E.			0	13. 7	17.66	31 97	31.24	
						10	13. 6	17.66	31.97	31.24	
						20	12 7	17.80	32.22	31.48	
						40	12. 7	19.29	34.87	34.01	
						60	10.18	19 76	35.72	34.80	
						80	9.15	19.84	35.86	34 95	
						120	8.25	19 87	35 91	35.00	
						160	7. 4	19.95	36.05	35.13	
19	8	a. m.	59° 1′ N. 10° 3′.7 E.			0	14. 4	12.81	23.26	22.88	Larviks-fjord.
						10	14. 4	16.05	29.08	28.47	

Station	1898		Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour					Cl per litre	Salt per litre	Salt per mille	
	Septbr.				m.	0 C.				
	19				20	14. 2	16.66	30.17	29.53	Larviksfjord.
					40	13. 9	18.41	33.31	32 52	
					60	13.05	18.83	34.05	33.20	
					80	12. 4	19.01	34 38	33.54	
					120	8. 3	19.76	35.72	34.80	
	Octbr		59⁰ 1′ N.							
	8		10⁰39′ E.		. 0	12. 3				
					10	13. 0	18.09	32.72	31.96	
					20	13. 0	18.41	33.31	32.52	
					40	13. 0	18.55	33.56	32.76	
					60	12. 1	19.29	34 87	34.01	
					80	8 55	19.77	35.72	34.81	
					120	8. 2	19.77	35.72	34.81	
					150	7. 5	19.89	35 96	35.04	
					300	6. 9	19.89	35.96	35.04	
	11				0	11. 1	14 56	26.40	25.90	Filtvedt.
					10	13. 4	17.97	32.51	31.75	
					20	13 2	18.34	33 18	32.40	
					40	11. 0	18.62	33.68	32.87	
					60	6. 8	19.04	34.42	33.58	
					80	6.55				
					120	6. 2	19.59	35.42	34 53	
					200	6. 0	19.77	35.72	34.81	
	10				0	10. 3	0 78		1.40	Drammensfi.
					10	11.85	10.17		17.87	
					20	9.65	14.05	25.49	25.03	
					30	4. 8	16.01	29.01	28.41	
					40	4. 6	16.69	30.22	29 58	
					60	4. 6	16.97	30.72	30.05	
					80	4. 6	17.12	30.99	30 31	
					120	4. 6	17.19	31 11	30.43	

b) Observations at Drøbak, Winter time (Bie).

	Feb.									
	7	9 a .m.	Drøbak.		0	1. 0	15.80	28.63	28.05	
	8	9 a. m.			0	1. 0	15.74	28.52	27.95	
	9	9 a. m.			0	1. 0	15.64	28.34	27.77	
	10	9 a. m.			0	0. 5	16.00	28.99	28.39	
	10	10 a. m.			0	0. 5	15.70	28.45	27.88	
					10	4 0	17.60	31 86	31.14	
					20	7. 0	18 79	33.97	33.15	
					40	7. 5	19.26	34.81	33.95	

Station	February 1898		Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour					Cl per litre	Salt per litre	Salt per mille	
					m.	° C.				
	10		Drøbak.		60	7. 8	19 42	35.10	34.23	
					80	7. 6	19 65	35.53	34.63	
					120	7. 0	19.69	35.60	34.70	
	11	9 a. m.			0	1. 5	16.33	29.57	28.94	
	12	9 a m			0	2. 2	16.70	30.24	29.60	
	13	9 a. m.			0	3. 5	17.20	31.13	30.45	
	14	9 a. m			0	3. 0	17.00	30.77	30.10	
	15	9 a. m.			0	2. 5	16.67	30.19	29.54	
	16	9 a. m.			0	3. 5	17.46	31.60	30.89	
					10	3. 8	17.56	31.79	31.07	
					20	4 0	17.66	31.97	31.24	
					40	5. 0	18.19	32.90	32.13	
					60	6. 8	18 92	34.23	33.38	
					80	7. 2	19 32	34.92	34.06	
					120	7. 4	19.59	35.42	34.53	
	17	9 a. m			0	1. 5	16.17	29.28	28.67	
	18	9 a. m.			0	1. 5	16.10	29.17	28.55	
	19	4 a. m.			0	1. 2	16.17	29.28	28.67	
	20	9 a m			0	1. 4	16.43	29.75	29.12	
	21	9 a m.			0	1. 0	16.30	29.52	28.89	
	22	9 a m.			0	0. 8	16.33	29.57	28.94	
	23	9 a. m.			0	1. 8	16.53	29.93	29.30	
					10	5. 0	18.09	32.72	31.96	
					20	6. 8	19.09	34.51	33.66	
					40	7. 0	19 59	35.42	34.53	
					60	6. 8	19.69	35.60	34.70	
					80	7. 0	19 72	35.65	34.76	
					120	7. 0	19.72	35.65	34.76	
	24				0	0. 7	16.37	29.64	29.01	
	25				0	0. 8	16.33	29.57	28.94	
	26				0	2. 2	17.70	32.04	31.31	
	27				0	1. 8	16.70	30.24	29.60	
	28				0	2. 5	17.33	31.36	30.66	
	March 1				0	2. 5	17.06	30.88	30.21	
	2				0	2. 4	16.50	29.88	29.25	

Station	March 1898		Locality	Soundings		Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
						m.	⁰ C.				
	2		Drøbak			10	2.8	16.67	30.19	29.54	
						20	3.8	16.80	30.42	29.77	
						40	4.0	17.80	32.22	31.48	
						60	5.5	19.59	35.42	34.53	
	3					0	2.0	16.57	30.01	29.37	
	4					0	1.5	16.80	30.42	29.77	
	5					0	1.0	16.80	30.42	29.77	
	6					0	1.4	16.80	30.42	29.77	
	7					0	0.8	16.91	30.61	29.95	
	8					0	0.7	17.06	30.88	30.21	
	9					0	0.9	17.06	30.88	30.21	
	10					0	2.0	17.27	31.26	30.56	
						10	4.8	18.79	33.97	33.15	
						20	6.0	19.52	35.29	34.40	
						40	6.0	19.59	35.42	34.53	
						60	6.2	19.70	35.61	34.69	
						80	6.5	19.70	35.61	34.69	
	11					0	2.2	17.64	31.93	31.21	
	12					0	2.0	17.56	31.79	31.07	
	13					0	2.0	17.67	31.99	31.26	
	14					0	2.5	17.20	31.13	30.45	
	15					0	2.2	17.34	31.38	30.68	
	16					0	2.0	16.83	30.48	29.82	
	17					0	2.0	16.30	29.52	28.89	
						10	2.2	16.34	29.57	28.94	
						20	2.5	16.41	29.72	29.09	
						40	5.0	17.49	31.66	30.95	
						60	6.0	19.59	35.25	34.36	
						80	6.0	19.70	35.61	34.69	
						120	6.0	19.73	35.66	34.75	
	18					0	1.8	13.12	23.82	23.41	
	19					0	1.7	14.17	25.71	25.24	
	20					0	1.7	14.60	26.47	25.97	
	21					0	1.8	14.60	26.47	25.97	
	23					0	2.7	16.45	29.79	29.16	

Station	March 1898		Locality	Soundings		Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mill	
						m.	⁰ C.				
	23		**Drøbak**			10	4. 1	18 41	33.31	32.52	
						20	5. 5	19.62	35.47	34 56	
						40	6. 1	19.83	35.85	34.93	
						60	6. 1	19.83	35.85	34 93	
						80	6. 0	19.83	35 85	34 93	
						120	6. 0	19.83	35.85	34.93	
	24	9 a. m.				0	2. 2	16.35	29.61	28.97	
	25	—				0	1. 8	16.63	30.11	29.47	
	26	—				0	2. 0	17.20	31.13	30.45	
	27	—				0	2. 4	17.31	31.33	30.63	
	28	—				0	2. 2	18.73	33.87	33.05	
	30	—				0	2. 5	17.77	32.17	31.43	
	31	—				0	3. 0	17.87	32.34	31.59	
	April 1					0	3. 3	17.63	31.91	31.19	
	June 13					0	15. 3	10.45			
						10	15. 2	11.12	20.21	19.92	
						20	7. 1	17.98	32 53	31 77	
						30	6. 3	18 69	33.80	32.99	
						40	,	18.91	34.19	33.36	
						50	6. 1	18 98	34.32	33 48	
						68	6 2	19 05	34.44	33.62	
						80	6. 2	19 09	34.51	33.66	
						95	6. 3	19.16	34.65	33.79	

IV. Observations from the Southern coast and fjords, Summer and autumn 1898.

(Hjort and Schmidt-Nielsen).

IV. Observations from the Southern coast and fiords.

Station	July 1898		Weather	Locality	Sounding	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
					m.	m.	° C.				
	26	9 a. m.		58°55′ N. 9°51′ E.		0	14. 6	17.30	31.31	30 61	
						10	13.95	17.30	31 31	30 61	
						20	13 52	17.37	31.44	30.73	
						40	11.60	18.51	33.49	32.69	
						60	9. 6	19.01	34 38	33 54	
						80	8. 5	19.65	35.53	34 63	
						120	7. 7	19 97	36.08	35 16	
						200	7.15	20.05	36.23	35.30	
	26	9 p. m.		58° 1′ N. 7°50′ E.	170	0	13. 7	17 05	30.86	30.19	
						10	13. 7	17.26	31.24	30.54	
						20	11.65	18.51	33.49	32.69	
						30	10. 2	19.15	34.62	33 78	
						40	9.75	19.26	34.81	33.95	
						60	9. 2	19.48	35.21	34.33	
						80	8. 8	19 58	35.40	34.51	
						120	8. 2	19.80	35.79	34 88	
						170	7. 7	19.87	35.91	35.00	
	27	6 a. m.				0	12. 5	18.05	32.65	31.89	Lindesnes.
		7 p. m.		58°45′ N. 5°25′ E		0	8. 3	19.64	35.52	34.62	Jæderens rev
	30	9 a. m.		58°55′.5N. 5°40′ E.		0	12. 4	18.19	32.90	32.13	Hafrs Fiord.
						5	12. 4	18.22	32 96	32.19	
						10	10. 9	18 62	33.68	32.87	
						15	8. 7	18.86	34.10	33.26	
						20	8. 3	18.86	34.10	33 26	
						25	7.85	18.86	34.10	33.26	
						30	7.15	18.90	34.18	33.35	
						35	5.49	18.90	34.18	33.35	
						40	5. 3	18 90	34.18	33.35	
						45	5. 1	18 90	34.18	33.35	
						50	5. 1	18.90	34 18	33.35	
	Aug 1			58°49′.4N. 5°28′ E.		0	10. 9	19.01	34.38	33 54	
						20	9. 2	19.55	35.32	34.45	
						40	8. 8	19.55	35.32	34.45	
	8	4 p. m.		58°54′ N. 5°21′ E		0	12.85	18 41	33.31	32.52	
						10	12.55	18.41	33.31	32.52	
						20	10. 0	19.12	34.57	33.71	
						40	8. 4	19 60	35.42	34.53	
						60	7. 7	19.84	35.86	34.95	
						100	7. 0	19.90	35.98	35.05	
	11			58°55′ N. 5°46′ E.		0	12.28	17.12	30.99	30.31	Gaus Fiord.
						10	11. 8	17 44	31.56	30 86	
						20	10.45	18.76	33.92	33.10	
						40	9. 1	19.15	34.62	33 78	
						60	7.25	19.58	35.40	34.51	
						100	6. 8	19.87	35.91	35.00	
						180	6.61	19.87	35.91	35.00	

Station	1898		Weather	Locality	Soundings	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
	Aug.			59°12′ N.	m.	m.	° C				Skudesnes.
	16	5.30 p. m		5°20′ E.		10	13. 5	17.62	31.90	31.17	
						20	13.18	17 94	32.46	31.70	
						40	12.88	18.12	32.78	32 01	
						60	10.58	18.90	34.18	33.35	
						80	9.60	19.26	34.81	33.95	
						120	7.75	19.58	35.40	34.51	
						200	6.70	19.90	35.98	35.05	
						300	6.65	19 97	36.08	35.16	
				57°56′ N.							Lister.
	18	noon		7°1.5′ E.		0	15. 5	16 34	29.59	28.96	
						10	14. 9	16 48	29.84	29.21	
						20	13. 5	17.55	31.77	31.05	
						40	12. 1	18.48	33.43	32.64	
						60	9. 5	19.26	34.81	33 95	
						80	8.95	19.87	35.91	35.00	
						120	7. 8	19 87	35.91	35.00	
						250	6 9	19.97	36.08	35.16	
				58° 8′ N.							Lyngdals Fiord Søvig.
	18	5.30 p. m.		6°53.5′ E		0	17. 7	13.84	25.10	24.66	
						5	15. 4	15.41	27.93	27.37	
						10	12.05	18.16	32.86	32.08	
						20	7. 7	19.33	34.94	34.07	
						30	7. 2	19.33	34.94	34 07	
						40	6. 6	19.40	35.06	34.20	
						90	5. 9	19 44	35.14	34.26	
						200	5. 7	19.44	35.14	34.26	
				58° 6′ N.							Lyngdals Fiord. Entrance.
	18	7 p. m.		6°49′ E.	15	0	17. 1	13.98	25.36	24.91	
						5	15. 0	16.16	29.26	28 65	
						10	14. 1	16.80	30.42	29.77	
						15	13. 9	16.98	30.74	30.07	
				58° 3′ 5 N.							Oxe — Grenningen.
	23	3 p. m.		8° 6′ E.	90	0	16. 7	12.88	23.38	23.00	
						20	14. 1	16.76	30.35	29.70	
						40	10. 6	19.12	34.57	33.71	
						80	8. 4	19.76	35.72	34 80	
						150	7. 3	19.90	35.98	35.05	
	Septbr			59° 6′ 5N							Frier Fiord.
	30	8 a. m.		9°38′ E.		0	11. 3	3.17		5.68	
						5	13. 7	16.64	30.13	29.49	
						10	13. 8	17.00	30.77	30.10	
						20	11. 5	17.95	32.48	31.72	
						30	6. 9	19.08	34.51	33 65	
						40	6.05	19.23	34.76	33.89	
						60	5. 9	19.23	34.76	33.89	
						80	6. 0	19.30	34.89	34.03	
						90	5. 9	19.33	34.94	34.07	
	Octobr			58°52′ N.							
	1	8 a. m.		9°50′ E.		0	12. 4	16.23	29.39	28.77	Langesund.
						10	12. 4	16 27	29.46	28.83	
						20	12. 9	16 95	30.68	30.02	
						40	13. 7	18.25	33 01	32 24	
						60	12. 1	19.55	35.32	34.45	
						80	9. 0	19.77	35.72	34.81	

Station	1898		Weather	Locality	Soundings	Depth from which sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
					m.	m.	° C.				
	Octobr			58°52′ N.							
	1	8 a. m.		9°50′ E.		120	8. 0	19.97	36.08	35.16	
						200	7. 2	19.97	36.08	35.16	
						350	6. 7	20.01	36.16	35.23	
				58°56′ N.							
	1			9°48′ E.		0	12. 5	16.34	29.59	28.96	**Langesund.**
						10	12. 4	16.45	29.79	29.15	
						20	12. 9	17.19	31.11	30.43	
						40	13. 7	18.62	33.68	32.87	
						60	11.75	19.65	35.53	34.63	
						80	9. 1	19.77	35.72	34.81	
						120	7. 8	19 84	35.86	34.95	
						200	7. 3	19.97	36.08	35.16	
				59° 1′ N.							**Langesunds**
	1	noon.		9°46′.5E.		0	12. 1	9.99			**Fiord.**
						10	12. 9	16 30	29.52	28.89	
						20	13. 9	17.70	32.04	31.31	
						40	12. 3	18.48	33.43	32.64	
						60	11. 5	19.26	34.81	33.95	
						80	8. 5	19.61	35.45	34.55	
						120	6. 5	19.61	35.45	34.55	
	1			Brevik.		0	12. 1	10.45	18.99	18.74	
						5	12. 6	16.02	29.02	28.42	
						10	13. 4	16.34	29.59	28.96	
						20	13.85	17.47	31.62	30.91	
						40	12. 3	18.48	33.43	32.64	
						60	11. 6	19.26	34·81	33.95	
						80	8. 2	19.37	35.01	34.14	
						100	6. 4	19.61	35 45	34.55	
	7			Lange-sund.		0	12. 6	16.45	29.79	29.16	
						10	13. 5				
						20	13. 4	18.47	33.42	32.62	
						40	13. 2	18.86	34.10	33.26	
						60	12.65	19.29	34.87	34.01	
						80	10.20	19.77	35.72	34.81	
						120	7. 6	19.97	36.08	35.16	
						200	7. 3	19.97	36.08	35.16	
	Decbr.			59°6′.5N.							
	6			9°38′ E.	85	5	8.55	15.71	28.47	27.89	**Frier Fiord.**
						20	9.25	18.06	32.67	31.91	
						30	8. 7	18 73	33.87	33.05	
						40	5. 8	19.26	34.81	33.95	
						60	5. 5	19.30	34.89	34.03	
						85	5. 8	19.30	34.89	34.03	
	6			Brevik.		0	4.95	7.18			
						5	8. 2	16.00	28.99	28.39	
						20	8. 2	17.88	32.36	31.61	
						30	8. 5	18.31	33.12	32.34	
						60	8.45	19.62	35.47	34.56	
						100	7. 6	19.69	35 60	34.70	
	6			Stathelle.		20	8. 1	18.06	32.67	31.91	

V. Supplements to the Surface Charts of the Skagerak and the North Sea 1896—1898.

V. Supplements to the Surface Charts of the Skagerak and the North Sea 1896—1898.

a) Christianssand—Antwerp December 1896, s|s Odin, Capt. Eitzen.

Station	December 1896		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
							° C.				
	19	5 a. m.		Oxs lighthouse.		0	5.25	17.79	32.51	31.76	
		8 —		57°37' N. 7°43' E.		0	4.75	17.67	31.95	31.24	
		10 —		57°18' 7°28'		0	6	19.30	34.85	33.99	
		12 noon.		56°58' 7° 9'		0	7.50	19.59	35.42	34.53	
		2 p. m.		56°37' 6°55'		0	7.50	19.42	35.10	34.23	
		4 —		56°21' 6°41'		0	7.50	19.56	35.35	34.47	
		6 —		56° 4' 6°28'		0	8	19.57	35.38	34.50	
		8 —		55°46' 6°13'		0	8	19.50	35.25	34.36	
		10 —		55°31' 6° 0'		0	8	19.62	35.47	34.56	
		12 night.		55°13' 5°45'		0	8	19.54	35.32	34.42	
	20	2 a m.		54°56' 5°36'		0	8.50	19.59	35.42	34.53	
		4 —		54°40' 5°25'		0	8.50	19.55	35.33	34.45	
		6 —		54°22' 5°15'		0	7	19.55	35.33	34.45	
		8 —		54° 5' 5° 5'		0	7.50	19.64	35.52	34.62	
		10 —		53°46' 4°56'		0	8	19.78	35.75	34.83	
		12 noon.		Terschelling Lightship.		0	6.50	18.43	33.33	32.54	
		2 p. m.		53°12' 4°33'		0	6	18.02	32.60	31.87	
		4 —		Haak Lightship.		0	6	18.29	33.09	32.30	
		6 —		52°41' 4° 5'		0	7	19.88	35.93	35.01	
		8 —		52°23' 3°52'		0	7	19.88	35.93	35.01	
		10 —		52° 6' 3°40'		0	7	19.37	34.76	33.89	
		12 night.		Schouwen Lightship.		0	5.50	17.87	32.32	31.57	
	26	4 p. m.		Schouwen Lightship.		0	6	18.19	32.90	32.11	

Station	December 1896		Weather	Locality	Soundings	Depth from which the sample obtained	Temperaturo of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt por mille	
							° C.				
	26	6 p. m.		52° 9′ N. 3°43′ E.		0	650	19.35	34.98	34 12	
		8 —		52°26′ 3°55′		0	7	19.35	34.98	34 12	
		10 —		52°45′ 4° 8′		0	7	19.52	35 29	34.40	
		12 night.		53° 2′ 4°21′		0	7	19.17	34.82	33.96	
	27	2 a. m.		53°15′ 4°36′		0	7	18.93	34 24	33.40	
		4 —		53°32′ 4°53′		0	7.50	19.64	35.52	34.62	
		6 —		53°51′ 5° 0′		0	7.50	19.44	35.14	34 27	
		8 —		54°10′ 5° 6′		0	7.50	19.73	35.66	34.75	
		10 --		54°27′ 5°20′		0	7.50	19.84	35.86	34.95	
		12 noon.		54°45′ 5°42′		0	7.50	19.73	35.66	34.75	
		2 p m.		55° 4′ 5°50′		0	7.50	19.83	35.85	34.93	
		4 —		55°20′ 6° 0′		0	7.50	19.78	35.75	34 83	
		6 --		55°41′ 6°10′		0	7 50	19.74	35.69	34.78	
		8 —		55°58′ 6°23′		0	7.50	19.74	35.69	34 78	
		10 --		56°15′ 6°36′		0	7.50	19.60	35.42	34.58	
		12 night.		56°33′ 6°50′		0	7.50				

b) Christianssand—Antwerp November 1897. s\|s Anvers, Capt. Eitzen.

	1897 Novbr. 6	$10^1/_2$ a. m.		Oxø lighthouse.		0	9	15.64	28.34	27.77	
		12 noon.		57°51′ N. lat. 7°53′ E. longd		0	9.25	17.81	32.24	31.50	
		2 p. m.		57°35′ 7°40′		0	9.50	18.44	33.36	32.57	
		4 —		57°21′ 7°30′		0	10	19.71	35.62	34.71	
		6 —		57° 5′ 7°25′		0	10.25	19.71	35.62	34.71	
		8 —		56°50′ 7° 0′		0	10.50	19 74	35.68	34.77	
		10 —		56°35′ 6°50′		0	10.50	19.80	35.79	34.88	
		12 night.		56°21′ 6°40′		0	11	19.85	35.88	34.96	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
							° C				
	Novbr. 7	2 a. m.		56° 7′ N. 6°26′ E.		0	11.25	19.94	36.04	35.12	
		4 —		55°52′ 6°13′		0	11.50	19.91	35.99	35.07	
		6 —		55°39′ 6° 3′		0	11.50	19.80	35.79	34.88	
		8 —		55°25′ 5°50′		0	11.50	19.94	36.04	35.12	
		10 —		55° 7′ 5°38′		0	11.50	19 91	35.99	35.07	
		12 noon.		54°47′ 5°20′		0	11.75	20.01	36.16	35.23	
		2 p. m.		54°33′ 5°13′		0	11.75	19.98	36.10	35.19	
		4 —		54°19′ 5° 5′		0	12	19.91	35.99	35 07	
		6 —		54° 5′ 4°55′		0	12	19.88	35.93	35.01	
		8 —		53°51′ 4°48′		0	12.25	19.77	35.72	34.81	
		10 —		53°37′ 4°40′		0	11.50	19 63	35.51	34.61	
		12 night.		53°23′ 4°28′		0	11	19.63	35.51	34.61	
	8	2 a. m.		53°10′ 4°15′		0	10.50	19.38	35.03	34.16	
		4 —		53° 0′ 4° 0′		0	11	19.56	35.35	34.47	
		6 —		52°46′ 3°52′		0	11.50	20.10	36.32	35.37	
		8 —		52°32′ 3°44′		0	12	20.12	36.36	35.45	
		10 —		52°18′ 3°35′		0	12	20 12	36.36	35.45	
		12 noon.		52°10′ 3°27′		0	11.50	20.10	36.32	35.37	
		7 p. m.		Schowen lighthouse.		0	11.25	18.69	33.80	32.99	

Antwerp—Christianssand, November 1897. S|s Anvers, Capt. Eitzen.

	Novbr. 13	8½ p. m.		Schouwen ligthouse.		0	10.75	18.69	33.80	32.99	
		8 —		52°25′ 3°53′		0	10.75	19.41	35.08	34.21	
		11½ —		Haaks ligthouse.		0	10.75	19 74	35.68	34.77	
	14	4 a. m.		Terschelling ligthouse.		0	10	19.19	34.69	33 84	
		8 —		54° 0′ 5°10′		0	11	19.53	35.30	34.40	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
							° C.				
	14	12 noon.		54°30′ N. 5°27′ E.		0	11.75	19.77	35.72	34.81	
		4 p. m		55° 2′ 5°45′		0	11.50	19.96	36.07	35.15	
		8 —		55°35′ 6° 8′		0	11.25	19.83	35.85	34.93	
		12 night.		56° 7′ 6°28′		0	11.25	19.83	35.85	34.93	
	15	4 a. m.		56°36′ 6°50′		0	10.50	19.80	35.79	34.88	
		8 —		56°55, 6°48′		0	10 25	19.87	35.91	35.00	
		12 noon.		57° 5′ 7° 0′		0	9.50	19.80	35.79	34.88	
		8 p. m.		57°18′ 7°20′		0	9	18 17	32.88	32.10	
		12 night.		57°42′ 7°38′		0	9 50	17.79	32.30	31 46	
	16	4 a. m.		Oxe ligthouse		0	9.25	16.18	29.30	28.69	

c) Christianssand—Hamburg, November 1897, s\|s Kong Ragnar,
O. Jensen.

Station	Date	Hour	Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Cl per litre	Salt per litre	Salt per mille	Remarks
	Novbr. 7	8¾ a. m.		58° 1, N. 8° 4′ E.		0	9	15.43	27.96	27.40	
		9½ —		57°49′ 7°53′		0	9.50	16.23	29.39	28.77	
		10½ —		57°40′ 7°45′		0	10	18.51	33.49	32.69	
		12 noon.		57°27′ 7°33′		0	9.75	19.53	35 30	34.40	
		2½ p. m.		57° 5′ 7°12′		0	9.50	19.11	34.55	33.70	
		4 —		56°51′ 7° 0′		0	10	18.93	34.24	33.40	
		5 —		56°40′ 6°54′		0	10	18.90	34.18	33.35	
		6 —		56°30′ 6°46′		0	10.50	19.00	34.36	33.51	
		7 —		56°19′ 6°40′		0	10.50	19.18	34.69	33.83	
		8 —		56° 9′ 6°35′		0	11	19.25	34.81	33 94	
		9 —		56° 0′ 6°32′		0	11	18.93	34.24	33.40	
		10 —		55°51′ 6°28′		0	11	18 86	34.10	33.26	
		11½ —		55°38′ 6°25′		0	11	18 90	34.18	33.35	
	8	1 a. m.		55°25′ 6°35′		0	11	18.72	33.85	33.04	
		2½ —		55° 9′ 6°46′		0	10.50	18.37	33.23	32.45	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
							° C.				
	8	4 a. m.		54°55' N. 6°57' E.		0	10	18.02	32.60	31.84	
		5¼ —		54°42' 7°10'		0	9.50	17.32	31.35	30.64	
		6¼ —		54°30' 7°25'		0	9	17.11	30.97	30.29	
		7½ —		54°20' 7°36'		0	9	17.60	31.86	31 14	
		8¼ —		54°10' 7°47'		0	9	17.64	31.93	31.21	
		9 —		54°10' 7°58'		0	9	17.53	31.73	31.02	
		10 —		54° 6' 8°12'		0	9	17.46	31.60	30 89	
		10¾ —		54° 2' 8°20'		0	8.50	18.58	33.61	32.81	
		11½ —		53°58' 8°35'		0	8	15.29	27.72	27.17	
		12 noon.		53°53' 8°43'		0	7	12.97	23 55	23.15	

d) Grangemouth—Christianssand, November 1897. S/s „Norway“.

	Novbr. 25	12 noon.		56°26' N. 0°52' W.		0	9.75	19.88	35.93	35 01	
		1 p. m.		56°28' N. 0°40' W.		0	9.75	19.91	35.99	35.07	
		2 —		56°31' N. 0°24' W.		0	9.50	19.99	36.15	35.20	
		3 —		56°34' N. 0° 8' W.		0	9.50	19.99	36.15	35.20	
		4 —		56°36' N. 0° 7' E.		0	9.50	19.96	36.07	35.15	
		5 —		56°38' 0°21'		0	9.50	20.06	36.25	35 33	
		6 —		56°41' 0°36'		0	9.25	20 06	36.25	35.33	
		7 —		56°44' 0°52'		0	9	20.06	36.25	35.33	
		8 —		56°47' 1° 7'		0	9	20.06	36.25	35.33	
		9 —		56°50' 1°23'		0	9	20 06	36.25	35.33	
		10 —		56°53' 1°39'		0	9	20.09	36.28	35.36	
		11 —		56°5[illegible]' 1°[illegible]'		0	9	20.06	36.25	35.33	
		12 night.		56°57' 2° 9'		0	8.50	20 09	36.28	35.36	
	26	1 a. m.		57° 0' 2°23'		0	8.50	20.06	36.25	35 33	
		2 —		57° 2' 2°38'		0	8.50	20.06	36.25	35.33	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth ° C.	Saline contents			Remarks.
	Date	Hour						Cl per litre	Salt per litre	Sait per mille	
	26	3 a. m.		57° 5′ N. 2°52′ E.		0	8.50				
		4 —		57° 8′ 3° 7′		0	8	20.06	36 25	25.33	
		5 —		57°10′ 3°22′		0	8	19.26	34.81	33.95	
		6 —		57°12′ 3°36′		0	8	19.26	34.81	33.95	
		7 —		57°14′ 3°50′		0	8	19.11	34.55	33.70	
		8 —		57°17′ 4° 8′		0	8	19.11	34.55	33.70	
		9 —		57°20′ 4°26′		0	8	18.94	34.25	33.41	
		10 —		57°23′ 4°44′		0	8	18.94	34.25	33.41	
		11 —		57°26′ 5° 2′		0	8	18.94	34.25	33.41	
	26	12 noon.		57°29′ 5°20′		0	8.25	18.94	34.25	33.41	
		1 p. m.		57°32′ 5°38′		0	8.50	18.65	33.74	32.92	
		2 —		57°35′ 5°55′		0	8.50	18.58	33.61	32.81	
		3 —		57°38′ 6°12′		0	8.50	18.58	33.61	32.81	
		4 —		57°41′ 6°30′		0	8.50				
		5 —		57°44′ 6°48′		0	9	18.65	33.74	32.92	
		6 —		57°47′ 7° 6′		0	9	18.79	33.97	33.15	
		7 —		57°50′ 7°23′		0	9	18.58	33.61	32.81	

e) Christiania—Fredrikshavn. ˢ|ₛ **Baldur,** Capt. Olsen.

	Novbr.										
	4	9 a. m.		Spro.		0	6	11.32	20.57	20.27	
		1 p. m.		Baste.		0	10. 5	15.32	27.78	27.22	
		3 p. m.		Veierland.		0	6	10.03	18.13	17.88	
		4½ —		Humbjerget.		0	7	12.48	22.66	22.30	
		11 —		58°54′ N. 10°10′ E.		0	8	12.81	23.26	22.88	
	5	1 a. m.		58°39′ N. 10°17′ E.		0	8. 5	16.95	30.68	30.02	
		3 —		58°23′ N. 10°26′ E.		0	8. 5	15.53	28.14	27.58	
		5 —		58° 8′ N. 10°34′ E.		0	9	12.75	23.15	27.77	
		7 —		57°52′ N. 10°42′ E.		0	9	12.07	21.93	21.59	
		9 —		57°34′ N. 10°42′ E.		0	9	13.19	23.94	23.53	

Station	November 1897		Weather	Locality	Soundings	Depth from which the sample obtained	Temperature of the water at that depth	Saline contents			Remarks
	Date	Hour						Cl per litre	Salt per litre	Salt per mille	
							° C.				
	8	4 p. m.		Skagen.		0	9	12.98	23.56	23.17	
		6 -		58° 4' N. 10°36' E.		0	8. 5	12.68	23.02	22 65	
		8 —		58°21' N. 10°27' E.		0	8. 5	18.24	32.99	32.22	
		10 —		58°38' N. 10°18' E.		0	7	15 59	28.25	27.68	
	1898 Febr. 10	9 a. m.		Spro		0	0	15.57	28 21	27.65	
		$10^1/_2$ —		Kjøvangen.		0	2	16.97	30 72	30 05	
		12 noon.		Revlingen		0	4	18.19	32.90	32.13	
		2 p. m.		Valle		0	2	17.18	31.09	30.42	
		$4^1/_2$ —		Svene.		0	2	17.18	31 09	30.42	
		11 —		58°52' N. 10°10' E.		0	3. 5	18.09	32 72	31.96	
	11	1 a. m.		58°33' N. 10°18' E.		0	6	19.75	35.71	34.80	
		3 —		58°17' N. 10°25' E.		0	5. 5	19.62	35.47	34.56	
		5 —		58° 0' N. 10°38' E.		0	6	20.02	36.18	35.25	
		7 —		Skagen light-ship		0	4	19.36	35 00	34 13	
		9 —		Hisholmen lighthouse.		0	4. 5	18.46	33.40	32 60	
1	March 10	$9^1/_2$ a. m		Degerud.		0	1. 0	16.99	30 75	30 08	
2		1 p. m.		Rævlingen.		0	3. 5	17 49	31 66	30.95	
3		3 —		Vrængen.		0	1. 0	15 94	28 88	28.29	
4		5 —		Larviksfiord.		0	1. 5	10 49	19.06	18.81	
5		11 —		Svener.		0	1. 5	14 89	27.00	26.48	
6	11	1 a. m.		58°38' N. 10°20' E.		0	1. 5	15.43	27.96	27.40	
7		3 —		58°19' N. 10°29' E.		0	1. 0	13.30	24.14	23 73	
8		5 --		58° 0' N. 10°40' E.		0	1. 0	12.79	23.22	22.84	
9		7 —		Skagensbugt.		0	1. 5	14.89	27.00	26.48	

r 1896				11 December		14 December 1896							
14		15		16		17		18		19		20	
0	0—50	0	0—50	0	0—50	0	0—50	0	0—50	0	0—50	0	0—50
3.3		2.5		3.8		3.5		2.0		5.5		4.5	
7.96		27.74		29.53		29.57		29.53		31.14		30.90	
c	c	+	+		+	+	+	r	+		r		
+	+	+	+	r	+	+	r	+	+		+		
r	+	r				r	r		r				
r	+	r		r		r	r	r	+		r		
	+	r			r	r	r	r	r	r	+	r	r
r	r	r	r		r			r					

6

31.

cc

r

r

		30/11		4/12						30/11			14/12
L_3		L_6		L_1		L_2		L_3		H_3		H_4	H_1
0	0—50	0	0—50	0	0–50	0	0–50	0	0—50	0	0–50	0	0
6.7		6.7		4 8		6.0		6.1		7.0		6.9	6.7
31.07		31.78		29.07		31.91		31 91		30.64		31.24	
cc	cc	cc	c	cc	cc	cc	c	c	cc	cc	cc	cc	cc
r		r	r	r	+	+	+	+	+		+	+	
		r		r	r						r		r
r		r	r	r			r				r		r

3. Christiania-Fjord. March 1897.

Date: March.	20									21	
Station.	21		22		23	24				25	
Depth in m.	0	0—40	0	0—40	0—40	0	0—40	0—100	0—200	0	0—40
Temperature.	0.5	(2.85)	0.8	(2 4)	(2.02)	0.8		(6.2)	(6.6)	1.95	(5 7)
Salinity ⁰/₀₀.	25.06	(33.20)	25.06	(32.73)	(32.69)	29.66		(34.68)	(35.04)	32.03	(33.62)
Cilioflagellata.											
eratium tripos v. longipes.	r	+	r	+		+	+	+	+		r
eridinium divergens . . .		r									
Bacillariaceæ.											
a) Oceanic forms.											
oscinodiscus concinnus .		+		+				+		+	+
— oculus iridis	c	cc	cc	c	c	c	cc	cc	cc	cc	cc
hizolenia alata	r	+		+	r	+	+	+	+	r	+
hætoceras boreale	r	+	r	c	+	+	+	+	c		r
— criophilum					r	r			r	r	
— decipiens				r			r	+	+	r	r
halassiothrix Frauenfeldii.				r	+	+	r	+	+		r
— longissima					r						
itzschia seriata		r			r		+	+	+		+
b) Neritic forms.											
halassiosira Nordenskieldii	+	c	r	cc	cc	cc	cc	cc	cc	cc	cc
— gravida				r	r		r	r	r	+	r
— gelatinosa									r		
scinodiscus polychordus.										r	r
ptocylindrus danicus . .		r			r						
hizosolenia setigera . . .				r		r	r	r	r		
hætoceras teres		r		r	r	+	r		+		r
— breve		r		r			r	r	+		
— constrictum				r	r	r	r		r		
— curvisetum					r						
— debile				r	r	r	r	r	r	r	r
— diadema				r		+		r	r		
— sociale		r				+	+		+		
— scolopendra									r		
iddulphia aurita			r	r	+	+	+	+	c	c	c

896—

7/8

20

r

896—97.

1897							
7/3	24/3	31/3	8/4	13/4	23/4	28/4	1/5
2 0	0				4.5	6.0	7.
						r	
r	r	+	r	r	+	r	r
			r			r	
		r			r		

896—9

7/8	24/8
20	0
r	r

896—97.

1897							
7/3	24/3	31/3	8/4	13/4	23/4	28/4	1/
2 0	0				4.5	6.0	7.
						r	
r	r	+	r	r	+	r	r
			r			r	
		r			r		

AARSBERETNING
VEDKOMMENDE
NORGES FISKERIER
FOR
1900

UDGIVET AF NORGES FISKERISTYRELSE

4DE HEFTE **1900**

„MICHAEL SARS"
FØRSTE TOGT I NORDHAVET AAR 1900

UNDER LEDELSE AF

JOHAN HJORT

(FORELØBIG MEDDELELSE)

BERGEN
JOHN GRIEGS BOGTRYKKERI
1901

I januar 1899 oversendte jeg til indredepartementet et forslag til bygning, udrustning og drift af en damper til undersøgelse af de norske fiskerier og de nordlige have. Dette forslag blev saavel fra regjeringens, specielt hr. statsminister Steens, som fra stortingets side modtaget med den største interesse og liberalitet, saaledes at de nødvendige midler allerede i juli samme aar var bevilgede. Kort derefter fik jeg i opdrag at foretage en reise gjennem de forskjellige fiskerilande og derefter sammen med hr. marinekaptein C. Blom at fremlægge en plan for skibet.

Denne reises erfaringer bestemte mig meget snart til at opgive den skibstype, der tidligere har været brugt til lignende undersøgelsesfartøier, nemlig den kombinerede seil og dampyacht, og istedet at lægge den engelske, paa saa mange erfaringer udarbeidede, fiskedamper-type til grund for planen.

Medens de store tunge ekspeditionsskibe som Albatross, Blake o. s. v. kun kan anvende fangstapparater, mest bundskraber og smaa trawler, af en spændvidde af i det høieste 15 fod og som væsentlig er beregnede for fangst af lavere organismer, saa kan en moderne fiskedamper anvende trawler af de største dimensioner optil 120 fod spændvidde, liner af flere tusen favnes længde, eller drivgarn i et antal af optil 100 stkr. Saaledes gjorde jeg det til min opgave at bygge et skib, som støttet paa disse fiskedamperes erfaringer kunde anvende alle den moderne tids fiskeredskaber i videnskabens tjeneste.

En plan udarbeidet efter disse synspunkter blev antagen af regjeringen, og den 6te juli 1900 kunde damperen „Michael Sars“ forlade Fredriksstad mek. verksted.

I en senere udførlig afhandling vil jeg give en nøiagtig beskrivelse af skibets apparater.

Her skal bare omtales nogle almindelige synspunkter.

Som man af fig. 1 kan se ligner „Michael Sars“ i det væsentlige den engelske fiskedamper. Længden er 125 fod mellem perpendikulærerne, bredde 23, dybde agter 12 fod. For og agter er der stort

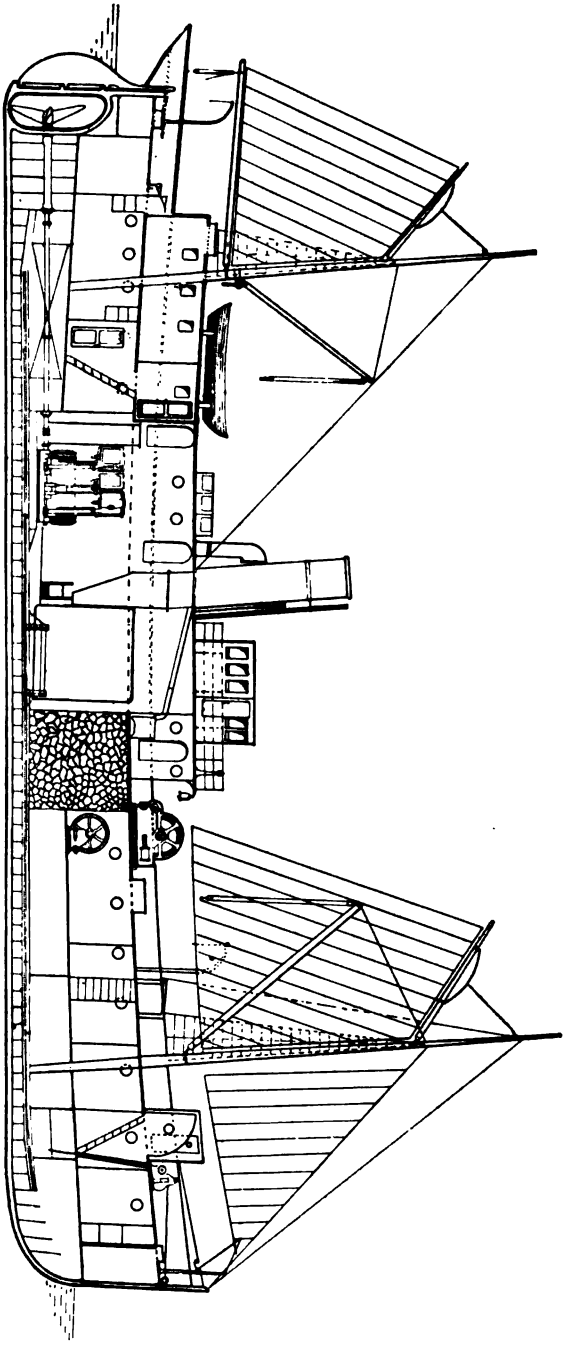

Fig. 1. „Michael Sars“.

spring i dækket. Seilene er smaa og skal bare tjene til at støtte skibet i storm. Maskinen er kraftig og giver skibet en fart af 10 knob. Foran maskinen har dækket en stor plads, hvor det meste arbeide udføres. Her staar den store 10 tons tunge winch, foran denne er lugen til det store lasterum, der tjener til lager for redskaber, kasser med glas, flasker o. s. v. Videre er i lasterummet anbragt en stor tromle med 4000 meter staalline for dybhavstrawling. Foran lasterummet er kahytter for maskinister og styrmænd samt mandskabsrum. Bag maskinen er et dækshus med laboratorium. Kahyt og salon for videnskabsmænd og kaptein er under dæk agter. Dækket paa begge sider af dækhuset er ganske frit, ligesaa rælingen, saaledes at der overalt her kan arbeides. Her er daviderne for hydrografi o. s. v. anbragt, og alt kan bekvemt oversees fra kommandobroen.

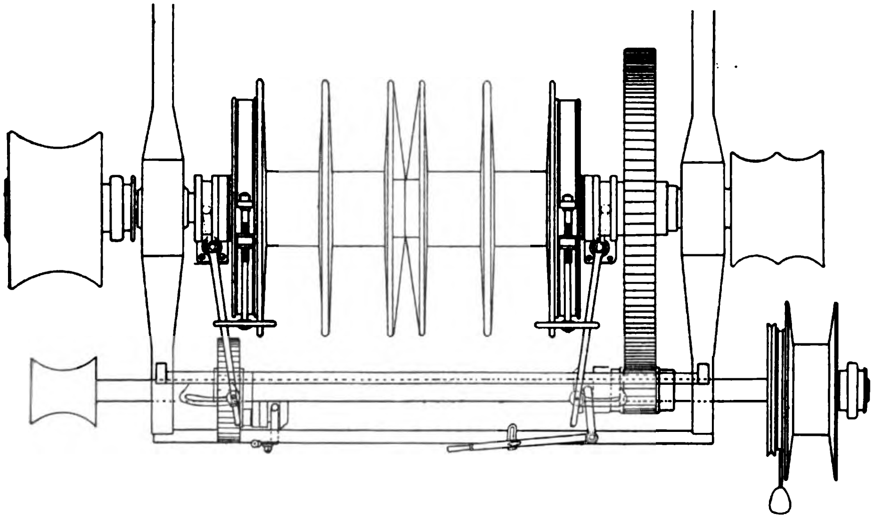

Fig. 2. Winchen.

Medens trawlen paa tidligere videnskabelige ekspeditioner i regelen blev manøvreret saaledes, at slæbelinen udgik fra den øverste ende af en svær lossebom eller raa, et arrangement hvorved linens udgangspunkt udsættes for de sværeste slingringer i større sjø, og medens man ved denne anordning trænger en svær akkumulator, søger fiskedamperne at bringe linens udgangspunkt saa nær vandfladen som mulig. De bruger aldrig akkumulator, men fanger linen op agter ved saakaldt „messenger“. Under slæbningen damper de altid forover, medens yachterne næsten altid damper agterover. Fiskedamperne benytter ogsaa wincher, hvis akse bærer tromlen for slæbelinen; herved undgaar man som paa yachterne

at maatte hive ind ved at føre linen flere gange rundt winch-nokk og derfra paa en tromle.

„Michael Sars"s winch kan udvikle en kraft af 20 hestekræfte Den langsomme akse gjør 10—12 omdreininger i minuttet og bære foruden nokkerne to store tromler, der kan holde 4000 meter 1¹⁄ staalline i 4 stykker. De forskjellige stykker kan sammenføies i e længde eller anvendes 2 ad gangen som ved ottertrawlen. Den hurtig akse bærer den hydrografiske tromle, der kan hive ind 120—150 meter

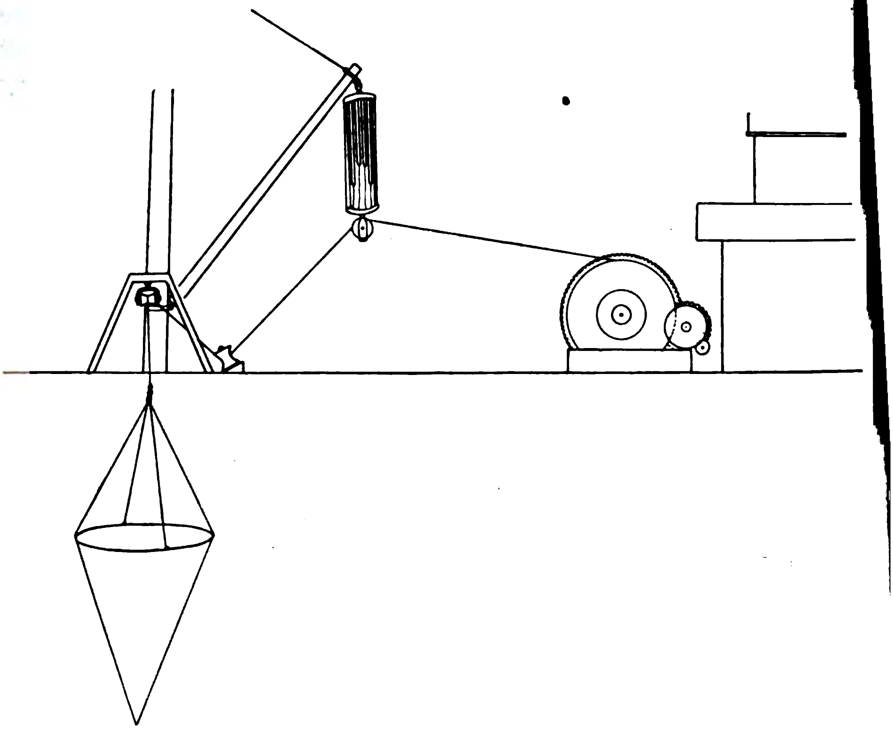

Fig. 3. Arrangement ved manøvre med den store vertikalhov.

minuttet, og har plads for 4000 meter staalline af 3 mm. gjennemsnit.

Fra winchen ledes slæbelinerne over ruller og blokker til galgerne, saaledes som paa trawldamperne.

Disse galger bliver nu anvendt saavel under fiskeri med trawler med otterbord, som under arbeide med de store hove. I sidste fald benyttede jeg en akkumulator af staalfjære af forskjellig længde, som bliver indsjaklet mellem winch og fodblok, hvad der paa ingen maade hindrer akkumulatorens funktion. Den store hov hives ind med winchen indtil hanefoden, derpaa lukkes den og tages paa dæk med en talje, anbragt i masten, samtidig med at wiren fra winchen slakkes. Paa denne maade var det muligt selv i sjøgang at bevare nettene for altfor sterke ryk, saaledes at vi selv i temmelig daarligt veir kunde arbeide.

Loddemaskinen (Lucas sounding machine, Telegraph construction & maintenance Co.) var anbragt paa styrbords række ud for den store winch og dreves ved hampeline, som gjennem en dobbelt blok førtes til et hjul paa winchens hurtige akse.

Dette arrangement gjorde det muligt at lodde paa bekvem maade uden at behøve en bro bygget indenfor rækken, saaledes som ellers har været brugeligt.

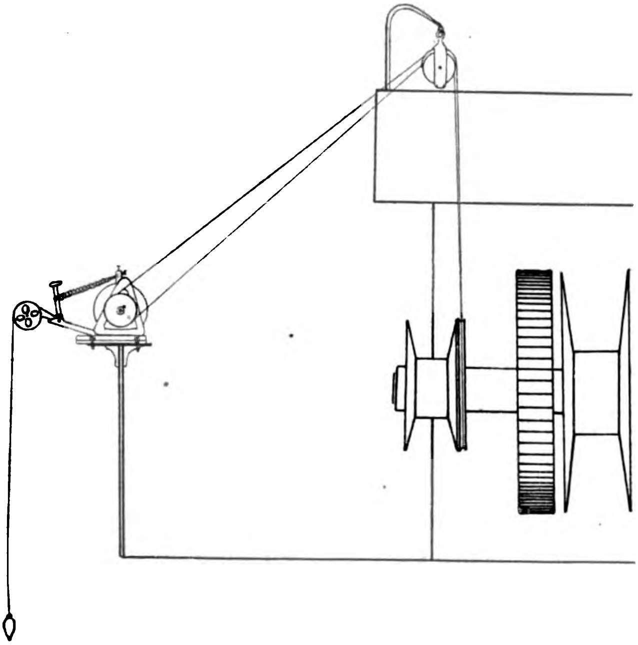

Fig. 4. Loddemaskinen i stilling.

Drivgarnene og fiskelinerne sattes fra agterdækket over bækken og droges fra fordækket, saaledes som fiskedamperne gjør det.

Ved temperaturundersøgelser og indsamlinger af vandprøver og plankton fra store dyb brugtes linen fra den ovennævnte winchtromle og førtes over meterhjul anbragt paa en stor david. Ved mindre dyb brugtes to mindre davider med tilhørende haandspil og tynde staalliner.

For at kunne udføre trawltræk i meget store dyb er der i lasterummet under den store winch anbragt en meget stor tromle med liden winch til oprulling, og denne tromles line bliver da som paa tidligere ekspeditioner indhivet over spilnokken paa den store winch paa dæk og oprullet af tromlen i rummet.

Ekspeditionen forlod den 22de juli Aalesund med kurs for kap Langanes paa Island, fuldførte paa veien de paa hosstaaende kart (Pl. I) med 5—10 betegnede undersøgelsesstationer og gik derefter langs Islands nordkyst om kap Nord til Dyrafjord paa nordvestsiden af Island (station 11—12). Fra Dyrafjord drog vi i retning NV. til den østgrønlandske isgrændse (station 13) og herfra igjen via kap Langanes til Jan Mayen. Paa hele denne lange strækning toges overalt mange stationer, især blev banken om Jan Mayen nøie undersøgt. Overalt fandt vi godt arbeidsveir med undtagelse af reisen mellem Island og Jan Mayen, hvor dybhavsobservationerne af denne grund blev noget ufuldstændige.

Fra Jan Mayen styrede vi mod Lofoten (station 29—47), fulgte herfra skibsleden til Nordkap, satte derfra kurs mod Bjørneøen (station 56—61) og vendte fra denne igjen efter paany i en stor bue at have krydset Nordhavet tilbage til Lofoten (stationerne 62—68). Foruden disse lange reiser, som tog med tiden fra 22de juli til 9de september, udførte vi videre i maanederne september, oktober og november endel undersøgelser i norske farvand fra og med Lofoten til Kristianiafjorden.

Det store materiale af hydrografiske data, bunddyr, planktonorganismer og erfaringer over fiskenes vandringer etc. etc., som indsamledes paa denne maade, har endnu langtfra ikke faaet sin grundige bearbeidelse. Ekspeditionen kan heller ikke betragtes som afsluttet, da vi om faa dage (den 22de januar) tiltræder en ny ekspedition, hvis hovedmaal det vil være at sammenligne vinterforholdene med sidste sommers. Paa de følgende sider skal der af den grund kun forsøges at fremdrage nogle enkelte problemer og belyse dem paa grundlag af de foreliggende resultater. Det følgende har ikke til hensigt at foregribe en senere nøiagtigere fremstilling, men kun at omtale nogle vigtige oceaniske problemer, som sandsynligvis om kort tid kommer til livlig at diskutteres, og hvis forstaaelse kanske kan befordres ved offentliggjørelsen af det følgende.

Som deltagere i ekspeditionen overtog hr. professor Nansen og hr. Helland-Hansen de hydrografiske undersøgelser. Hr. Gran overtog planktonundersøgelserne, medens jeg selv med bistand af assistent Wollebæk ledede fiskeforsøgene. Hr. professor Nansen konstruerede før afreisen en række af hydrografiske instrumenter, der senere af ham vil blive beskrevne. Han deltog 3 uger i ekspeditionen; senere overtog

hr. Helland-Hansen indsamlingen af vandprøver etc., hvilke han ogsaa senere analyserede. Førelsen af skibet og navigationen blev overtagen af hr. fiskeriinspektør Sørensen, hvis levende interesse for foretagendet og hvis gode navigation væsentlig bidrog til, at planerne lykkedes. I den følgende korte oversigt, der, som ovenfor anført, kun har til maal at belyse nærmere nogle specielle problemer, vil vi fremstille følgende:

I. De hydrografiske hovedresultater af Helland-Hansen.
II. Nogle vigtigere planktonorganismers udbredelse af H. H. Gran.
III. Fiskeforsøgene af mig selv.

Den udførlige fremstilling af hydrografien vil senere offentliggjøres i en afhandling af professor Nansen.

I.

Nogle hydrografiske hovedresultater.

Af B. Helland-Hansen.

Under henvisning til professor Nansens senere beretning gives her kun en ganske kort oversigt over de mest iøinefaldende hydrografiske forhold.

Paa grund af de smaa, men betydningsfulde variationer i de dybe have blev hovedvegten ved udrustningen og senere under selve arbeidet lagt paa at naa den størst mulige præcision. Det blev nødvendigt at gjøre mange forbedringer af de hidtil anvendte instrumenter og metoder. Her skal kun nævnes et par enkelte ting. — Af vandhentere havde vi med ialt 10 stykker, af forskjellig konstruktion, de fleste isolerende. Til de øvre vandlag brugtes dels Petterssons lille isolerende vandhenter, dels en af ham og Nansen senere konstrueret større med meget stor isolationsevne; paa de store dybder benyttedes for det meste en af prof. Nansen konstrueret, der viste sig at isolere udmerket selv fra de største dyb. Et væsentligt fremskridt i retning af nøiagtig temperaturbestemmelse var det, at disse isolerende vandhentere efter Nansens forslag forsynedes med fastsiddende termometre, som var stukket gjennem vandhenterens laag; kviksølvbeholderen ragede ned i vandhenterens inderste cylinder; hele termometret er omgivet af et sterkt glasrør, der nedentil er fyldt med kviksølv og forøvrigt for isolationens skyld gjort lufttomt. Herved har det været muligt at bestemme temperaturen meget sikkrere end med vendetermometer; et saadant sendtes dog ofte ned med vandhenteren til sammenligning. — For det meste tappedes der af vandhenterne 2 prøver, en til direkte specifik-vegt bestemmelse og en til at bestemme saltmængden ad kemisk vei (ved den almindelige titrering).[1] — I det følgende vil kun resultatet af titreringerne refereres. For praktisk at finde den nøiagtighed, hvormed saltmængden saaledes er bestemt, har jeg gjort dobbelttitreringer af 118 forskjellige vandprøver, fortrinsvis af saadanne,

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[1] Saltmængden angives i *pro mille*, d. v. s. gram salt i 1000 gram søvand. „Atlanterhavsvand“ indeholder altid mere end 35 $^0/_{00}$ salt, arktisk vand („polarvand“) altid mindre end 35 $^0/_{00}$.

hvor den første bestemmelse kunde antages at være feilagtig. Middelfeilen viste sig at være særdeles liden, omtrent 0,01 ‰ salt.

Paa planche I og II findes isotermer og isohaliner[1]) afsat paa en saadan maade, at de fleste mindre variationer er kommet med. Den paafaldende overensstemmelse paa mange punkter mellem temperatur og saltgehalt synes ogsaa at tillade, at man trækker konsekvenserne selv af de meget smaa variationer i titreringsresultaterne.[2]) De partier paa kartet, som ligger mellem snitlinierne, er selvfølgelig tegnet mer eller mindre frit og maa vel kanske ved en mere indgaaende behandling forandres. —

Efter den valgte rute har det været muligt at faa adskilligt indblik i forholdet mellem Atlanterhavsvand og arktisk vand. Vi har faaet karakteristiske snit gjennem „Golfstrømmen“ paa flere steder, gjennem „Irmingerstrømmen“ og fra farvandet nordenom Island, opover mod Jan Mayen.

Det ses, at det salteste vands („Golfstrømmens“) udbredelse i Nordhavet er væsentlig forskjellig i overfladen og i de dybere lag. Medens overfladevandet ved snit II er bøiet sterkt mod vest, nærmer den dyberegaaende strøm sig mere Norges kyst. Strømmen blir paa farten nordover stadig ferskere og koldere. I det sydlige snit er maksimumsværdien af salt over 35,40 ‰ (i vel 50 m.s dybde); temperaturen i overfladen er over 10°, optil 12° C, og over 5° fandtes helt ned til 3—400 meters dybde. I snit II naar ikke saltgehalten over 35,30 ‰, temperaturen i overfladen er mellem 8° og 10°, og allerede ved 150 m. passeres isotermen for 5 grader. Som nedenfor nævnt er imidlertid 3-grads isotermen rykket dybere ned i den nordligere del af strømmen. —

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[1]) ɔ: linjer, som er trukket gjennem punkter med samme temperatur eller saltgehalt.

[2]) Som eksempel kan anføres følgende række observationer af overfladevandets temperatur og saltmængde mellem stationerne 30 og 34 (snit II); observationerne er her tagne hver halve time under farten:

Temp.	Salt ‰
6,4	34,89
7,6	35,07
7,2	35,04
7,7	35,10
7,4	35,08
8,3	35,23
8,4	35,23
7,8	35,11
7,9	35,12

Kartet viser, at den salteste del af strømmen i overfladen paa vei nordover fra 63—64° n. b. ved 70° n. b. er veget længere bort fra Norges kyst henimod Jan Mayen. Denne forskyvning viser snit II tydelig. Derfra bøier overfladelaget igjen tilbage i østlig retning, indtil det ved omtr. 72° n. b. deler sig i 2 grene. Den salteste (optil 35,11 ‰ salt) gaar mod nord op forbi Beeren Eiland, i vest for øen. Den anden (kun lidet over 35,00 ‰) skyder ind mellem Norge og Beeren Eiland; 35-isohalinen forsvinder imidlertid allerede ved et par og tyve grader ø. l., idet det arktiske vand blir for mægtigt i overfladen; denne østligere gren viser jevnere saltgehalt og temperatur (vel 6°) end den anden. — Paafaldende er det, at mens de 4 isohaliner i „35-vand" i overfladestrømmens vestlige del mellem de 2 første snit omtrent følges ad parallelt og i nogen afstand fra hinanden, ser det ud som om de i den østlige del gaar vifteformig fra hinanden; i snit I er der meget kort afstand mellem dem, i snit II øiensynlig temmelig stor. Planktonundersøgelserne viser her en eiendommelig overensstemmelse med de hydrografiske observationer (sml. næste afsnit). Mellem st. 30 og 43 fandtes rent oceaniske planktonformer fra Atlanterhavet, for en stor del sammen med arktiske former. Paa station 43 fandtes for første gang i større mængde paa veien østover fra Jan Mayen den sydlige planktonform *Ceratium tripos* foruden kystplankton; desuden fandtes manæter og fiskeyngel, som maa være kommet fra land. De samme planktonformer fandtes paa snit I østenfor 1° v. l.; de stammer fra Nordeuropas kyster. Disse ting sammenholdt med de to hydrografiske snit viser, at vand fra Skotland og Norges kyster og fra Nordsøen rives med af „Golfstrømmen" og paa veien nordover breder sig ud mod vest i overfladen, men mindsker samtidig i tykkelse nær land. I „Golfstrømmen"s østlige parti foregaar blandingen efterhaanden under farten nordover. I den vestlige del derimod synes blandingen i overfladelaget for en stor del allerede at være fuldbyrdet ved 64°—65° n. b. Hid kommer en stor mængde arktisk vand ned fra nordvest, mellem Jan Mayen og Island, støder mod det nordovergaaende Atlanterhavsvand og blander sig med dette til en viss grad. Det mer eller mindre opblandede Atlanterhavsvand gaar saa i overfladen op „i læ af" Jan Mayen, men støder her paa en ny barriere af arktisk vand og tvinges mod øst, idet det blir opblandet videre. Derved dannes en stor kile af kystvand fra Norge syd for snit II, med spidsen mod nordvest. — Da det jo ikke er rimeligt, at ruten fra Jan Mayen mod Norge skulde falde nøiagtig sammen med en grænselinje for de hydrografiske forholds vedkommende, skal sandsynligvis kurverne her være adskillig mere takkede. At en slags grænselinje øst for den vældige Jan Mayen kegle virkelig findes, synes imidlertid a priori meget rimeligt.

Strømmens dybereliggende parti viser som sagt et noget andet løb, som staar i sammenhæng med havbundens form (banken). „35,2-vandet“ er i snit I optil 400 m. tykt og noget over 200 kvartmil bredt, i snit II kun optil 250 m. tykt, men over 250 kvartmil bredt. Det er altsaa strukket endel ud i retning øst—vest1). Samtidig er imidlertid 35,1-kurven flyttet fra omtr. 450 m. under overfladen til henimod 800 m.; der har altsaa fundet en sterk blanding sted i strømmens underste del mellem „35,2-vand“ og ferskere vand, da for en væsentlig del det arktiske vand, som trænger ind mellem Jan Mayen og Island; her er en sammenligning mellem de 2 snit meget interessant. Ogsaa isotermerne viser et lignende forhold; medens 5°-isotermen er rykket op nærmere overfladen, er 3° og 0°-isotermen rykket dybere ned, eftersom vi kommer nordover. — Snit III er øiensynlig typisk. Der findes i Atlanterhavsstrømmen langs Norges kyst et udpræget maksimum i saltgehalt i 70—100 meters dybde under overfladen; i denne dybde ender 35,2-kurven i en spids paa omtr. 72½° n. b.; vi er dog muligens her kommet lidt i kanten af „35,2-vandet“.2) Det ses, at i snit III følges følgende isotermer og dybestliggende del af isohalinerne temmelig nøiagtig ad: 4° og 35,20 ‰, 3° og 35,15 ‰, 2° og 35,10° /oo. I snit IV findes intet „35,2-vand“; i snit V kun paa st. 62,80 m. (35,23 ‰). Det viser sig, at den salteste af de 2 grene ogsaa i dybet er den, som stryger op vest for Beeren Eiland. Det synes, som om der findes „35,1-vand“ endnu et ikke ganske lidet stykke længere mod vest fra st. 64; her var i 300 m.s dybde en saltgehalt 35,11 ‰. Ved st. 62 og 63 gaar 3°-isotermen i 200 m.s dybde, men skraaner derefter sterkt opover mod vest (st. 64, 100 m. 2°,88 C.). Det kolde polarvand er jo ikke svært langt borte. —

Det arktiske vand har i 1900 vistnok været mægtigere i overfladen nord for Norge end almindeligt. Hele sommeren var ogsaa ualmindelig kold og raa der nord.3)

Snit I viser ogsaa den østislandske polarstrøm. Som et temmelig bredt lag trænger arktisk vand mod syd under den vestlige arm af Atlanterhavsvandet; det gaar langs Islands kyst helt op i overfladen som en sterk strøm. Isotermer og isohaliner følges ganske nøie. Om-

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1) De 2 snit er omtrent parallele og noget nær lodrette paa strømretningen.

2) At „35,2-vandet“ er tykkere paa stat. 68 end paa st. 46 skyldes vel for en væsentlig del tidsforskjellen; st. 46 er taget 13de august og st. 68 8de september; der var sen sommer i havet.

3) Paa st. 61 i nærheden af Beeren Eiland fandtes 4de september kuldegrader allerede i 20 m.'s dybde under overfladen. — Her kan ogsaa nævnes, at i det inderste af Porsangerfjord fandtes i 50 m.s dybde — 0°65 C., en forbausende lav temp. (34,24 ‰ salt). Længere ude, hvor fjorden var dybere, var temp. høiere, 3½°-7° C.

kring st. 9 ligger isotermerne for 4— 8° tæt ved hinanden i de øverste 70 m. Derfra gaar de ned mod begge sider; ved st. 10 har vi endnu i 160 m.s dybde 7°16 C. I overensstemmelse med Knudsens observationer paa den danske Ingolfekspedition viser det sig ogsaa paa vort snit VI mellem Island og Jan Mayen, at 35,0-isohalinen skraaner opover: den ligger nærmere overfladen ved Jan Mayen end ved Island. Ogsaa m. h. t. temperaturerne er der overensstemmelse med „Ingolfs“ resultater, idet der paa de forskjellige stationer fandtes 2 minima.[1])

Paa veien vestover langs Islands nordkyst (den nordlige rute paa kartet) fandtes kun et par steder „33-vand“, forresten var saltgehalten over 34 °/oo. Paa tilbageturen (den sydligere rute) fandtes adskilligt mere „33-vand“, dog ogsaa store partier vand af 34 °/oo. I den mellemliggende uge blæste der storm af N. En lidt nøiere granskning af observationerne synes at antyde, at der rundt Islands nordkyst den hele tid gik et belte af „34-vand“; „33-vandet“ paa veien mellem stat. 15 og 17 er rimeligvis kommet fra nordvest. Temperaturkurverne taler ogsaa for det, idet der ialfald for 7°-isotermens vedkommende er en sterk bøining mod sydost. Isen var vistnok ikke saa langt borte. — Paa station 11 fandtes allerede i 60 m.s dybde 35,02 °/oo salt og 6°12 C; „Irmingerstrømmen“ er meget skarpt bøiet af mod øst ved omtr. 67° n. b.

I Danmarksstrædet var forholdene høist interessante. Der var store vekslinger (ofte forskjellige „baand“) saavel i temperatur som saltgehalt, og overgangene var særdeles skarpe. Paa omkr. 25° 18′ v. l. og 66° 28′ n. b. fandtes kl. 1,20 a. m. 4de august i overfladen temp. 4°6 C. og saltgehalt 32,78 °/oo; 20 minuter senere, faa kabellængder derfra, 9°4 C. og 35,00 °/oo salt. Ogsaa i dybet synes der at ha været afvekslende forskjellige belter. Observationerne tyder paa, at „Irmingerstrømmen“ støder ret paa den sydgaaende polarstrøm ved vel 67° n. b. Disse forhold kan vi dog her ikke gaa nærmere ind paa.

Under de store strømsystemer i Nordhavet findes der paa de største dyb under 1000 m. mægtige lag af konstant saltgehalt 35,00—35,01 °/oo; titreringer af 26 forskjellige prøver fra dyb større end 1000 m. gav i 12 tilfælde 35,01, i 10 tilfælde 35,00 og kun 4 gange en værdi, som var et par pro mille forskjellig herfra. Paa disse dyb er temperaturen i regelen omkring — 1° C., undertiden lidt høiere, undertiden lidt lavere. I bundlagene paa de største dyb over 2500 meter er ogsaa temperaturen konstant — 1°2 C. Dette stemmer særdeles godt med prof. Mohns observationer paa den første norske Nordhavsekspedition.[1]) Disse lag undergaar rimeligvis ingen forandringer selv i løbet af meget lang tid.

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[1]) Den danske Ingolfekspedition. 2. Hydrografi af Martin Knudsen.

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[1]) Den norske Nordhavsekspedition 1876—78. H. Mohn: Nordhavets dybder, temperatur og strømninger.

II.

Nogle vigtigere planktonformers udbredelse i Nordhavet.

(Af **H. H. Gran.**)

Planktonundersøgelserne ombord paa Michael Sars sommeren 1900 udførtes med det maal for øie, at jeg vilde give et bidrag til løsningen af følgende to spørgsmaal, der allerede har været reist af tidligere forskere (Cleve, Hensen):

1. I hvilken udstrækning kan planktonorganismernes udbredelse give anledning til slutninger om vandmassernes bevægelser?
2. Hvilke havomraader er rigest paa fritsvømmende organismer, og hvilke er aarsagerne til den forskjellige rigdom paa de forskjellige steder?

I de sidste aar har forskjellige forskere, fremfor alle Cleve, forsøgt at finde et hjælpemiddel til at bestemme havstrømmenes bevægelse ved at undersøge de smaa fritsvømmende organismer, det saakaldte plankton. De fanges med hove af meget fin silkedug, som trækkes i søen horisontalt eller vertikalt og siler søvandet, saa at organismerne samles i bunden af hoven. Det er udenfor al tvil, at man ved denne methode kommer til meget vigtige resultater, som man ikke let kan naa ad anden vei; men man maa gaa frem med stor forsigtighed, naar man drager sine slutninger, det har jeg forsøgt at bevise i en tidligere afhandling.[1])

Ved mine planktonundersøgelser ombord paa Michael Sars forsøgte jeg derfor saa nøiagtig som muligt at bestemme udbredelsen af de enkelte arter for at se, til hvilken grad af nøiagtighed de forskjellige former kan benyttes som ledeorganismer til at bestemme de strømmende vandmassers oprindelse, ligesom geologerne bruger forsteninger eller

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[1]) Johan Hjort and H. H. Gran: Currents and pelagic life in the Northern Ocean. 1899. Bergens Museums skrifter, Vol. VI.

ledefossiler til at undersøge de geologiske lags sammenhæng og rækkefølge.

Ved de senere aars undersøgelser er det bragt paa det rene, at de forskjellige havomraader har hver sine karakteristiske dyr og planter, som er udrustede til at leve under de hydrografiske forhold, som findes paa stedet, men som ikke trives saa godt under andre forhold. De grunde kysthave har ogsaa sine karakterformer, som for størstedelen er afhængige af havbunden, idet de f. eks. maa gjennemgaa et fastsiddende udviklingsstadium.

Hvis nu en art, som ikke selv har nogen kraftig egenbevægelse, saa at den kan gjøre sig uafhængig af havstrømmene, findes udenfor det omraade, hvor den egentlig hører hjemme, saa er det meget sandsynligt, at den er hidført af strømmen. Findes kun ganske enkelte individer, saa kan man dog af deres forekomst ikke slutte mere end af andre enkelte drivende legemer som f. eks. strømflasker eller det sibiriske drivtømmer, som findes i Nordhavets nordvestlige dele: man kan ved hjælp af dem i mange enkelte tilfælde bestemme en strømretning, men man kan ikke trække op de nøiagtige grænser for de vandmasser, som kommer fra forskjellige dele af havet. Hvis dette sidste skal blive muligt ved biologiske iagttagelser, saa maa vandmassernes karakterformer i større mængde følge med under bevægelsen fremover, og man maatte anvende saadanne fangstredskaber, at man sikkert kunde konstatere, om vedkommende art findes paa stedet eller ikke, saa at man kan drage slutninger ogsaa af et negativt resultat.

Den biologiske methodes brugbarhed afhænger af løsningen af følgende to spørgsmaal:

1. Er de forskjellige organismer saa regelmæssig fordelt i havet, at man kan drage nogen hydrografiske slutninger af, om de findes eller mangler i en optagen prøve?
2. I hvilken udstrækning kan planktonorganismerne vandre med havstrømmene uden at gaa til grunde, naar vandmasserne lidt efter lidt forandrer sin hydrografiske karakter?

Det første af disse spørgsmaal kan temmelig let besvares ved direkte undersøgelse. Større organismer med livlige bevægelser, som svømmer omkring i sværme, kan ikke komme i betragtning. Som en almindelig regel gjælder det, at jo mindre organismerne er (indtil en vis grænse, som bestemmes af hovens maskevidde), desto sikrere kan man ved hjælp af enkle apparater afgjøre, om de virkelig lever paa et sted eller ikke. Derfor var det ganske naturligt, at Cleve begyndte med diatomeerne, da han forsøgte at finde sikre ledeorganismer; de hører til de mindste organismer i planktonet, og de kan optræde i store mængder, saa at chancerne er store for at fange dem, selv om man kun tager smaa prøver. Det samme gjælder ogsaa en anden gruppe af mikroskopiske alger, peridineerne, og tintinnerne, en gruppe af infusionsdyr, og desuden endel smaa krebsdyr.

De lidt større krebsdyr af copepodernes orden, saasom den almindelige *Calanus finmarchicus* (rødaat eller rødmar), *C. hyperboreus*, *Euchæta norvegica* og amphipoderne (*Parathemisto, Euthemisto*) ligesom ogsaa andre, for det blotte øie synlige dyr, f. eks. de bekjendte vingesnegle *Clio* og *Limacina* kan benyttes, naar man kun ikke fanger dem med for smaa og finmaskede redskaber. Desuden maa man tage i betragtning, at disse dyr kan forekomme paa et sted uden at kunne paavises i overfladen, da de kan hæve og sænke sig i vandet.

Det andet spørgsmaal er meget vanskeligere at besvare; vandringsevnen eller med andre ord akkomodationsevnen til forandringer i temperatur, saltholdighed &c. er forskjellig for de forskjellige arter. Enkelte, som findes omtrent overalt, synes at kunne taale meget store forandringer, f. eks. den lille copepode *Oithona similis;* disse kan ikke bruges som ledeorganismer af den grund, at de forekommer over hele det undersøgte omraade. Men der gives ogsaa former, som er saa ømfindtlige, at de kun kan vandre ganske korte strækninger udenfor det omraade, hvor de hører hjemme; saaledes er det bekjendt, at renden mellem Færøerne og Shetlandsøerne danner en skarp nordgrænse for halvparten af alle de arter, der lever i Golfstrømmen vestenfor Skotland. Andre kan blive ført videre med strømmen, men ganske enkeltvis, saa at de nordenfor optræder som rene sjeldenheder, medens hovedmængden af dem dør ud samtidig med at vandmasserne faar lavere temperatur og saltgehalt.

Saaledes er diatomeerne, som Cleve først benyttede som ledeorganismer, efter min erfaring mindre skikkede paa grund af deres eiendommelige biologiske forhold; de faa arter, som virkelig er oceaniske (f. eks. *Rhizosolenia styliformis, Chætoceras decipiens, Thalassiothrix longissima, Coscinodiscus radiatus*) findes enkeltvis over hele Nordhavet. Under gunstige omstændigheder kan de formere sig meget raskt, saa at de kan danne en tyk brungrøn grød i hoven. Ostenfeld har i sin sidste afhandling[1] gjort opmerksom paa, at denne kraftige opblomstring især finder sted i kystens nærhed eller paa andre steder, hvor der foregaar større blandinger i vandmasserne. Dette stemmer ogsaa med mine egne iagttagelser; derimod kan jeg ikke være enig med ham, naar han antager, at ingen diatomeer er ægte oceaniske organismer; jeg fandt f. eks. *Rhizosolenia styliformis* i store mængder midt paa havet mellem Jan Mayen og

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[1] M. Knudsen og C. Ostenfeld: Temperatur og saltgehalt paa islandske og grønlandske skibsrouter 1899. Kjøbenhavn 1900.

Norge i selskab med udelukkende oceaniske arter. Algen vegeterede kraftig, havde endog auxosporer, som tidligere ikke er kjendt hos denne art, og desuden en helt ukjendt form af sporedannelse (?), som senere vil blive beskreven, hvorved der dannes indtil 128 cellekjerner i hver celle.

Hvor diatomeerne optræder i store mængder, kan forskjellige arter eller samfund af arter dominere i forhold til de øvrige; det synes især at være temperaturen, som afgjør, hvilket af disse algesamfund skal formere sig sterkest. Det er disse samfund, som oprindelig dannede grundlaget for Cleves planktontyper og som i de fleste tilfælde gav dem navn (Trichoplankton af *Thalassiothrix*, Chætoplankton af *Chætoceras*, Styliplankton af *Rhizosolenia styliformis)*.

Hvilke arter i hvert tilfælde bliver dominerende, afhænger sandsynligvis af de hydrografiske forhold paa stedet; men da diatomeernes formering efter alle erfaringer maa foregaa meget raskt, vil man ved bestemmelsen af diatomeplanktonet ikke kunne faa vide meget mere om vandmassernes oprindelse, end det allerede kan afgjøres ved rent hydrografiske undersøgelser. Den sidste sommers undersøgelser viser ogsaa, at diatomeerne er meget uregelmæssig fordelt. Dette forhold kan kun forklares af deres eiendommelige livsforhold, at de snart formerer sig voldsomt, snart igjen forsvinder; naar der kun bliver enkelte individer igjen, vil de meget let undgaa observation.

Cleve har ogsaa senere indordnet andre organismer i sine typer, og hans opfatning af de forskjellige arters udbredelse stemmer i det store og hele med mine erfaringer.

De bedste ledeorganismer i Nordhavet har jeg fundet blandt peridineerne; deres udvikling er mere regelmæssig end diatomeernes, det beviser ogsaa deres optræden ved kysterne. Medens diatomeerne hvert aar har flere maksima og minima, har hver art af peridineerne en meget jevn formeringskurve; de formerer sig langsomt, naar et maksimum ved en bestemt aarstid og aftager saa igjen langsomt mod et minimum.

Peridineernes udbredelse i Nordhavet sommeren 1900 var meget regelmæssig; hver form havde sit vel begrænsede udbredelsesomraade med maksimum af hyppighed i centrum og minimum langs med periferien. Indenfor grænserne af dette omraade kunde vedkommende form paavises i hver eneste planktonprøve fra overfladen.

De vigtigste peridineer i Nordhavet er de mange former, som har været forenede under navnet *Ceratium tripos*, men som ialfald i Nordhavet er vel begrænsede; derfor har jeg i det følgende opført dem som arter.

Nordhavets peridineer danner 3 forskjellige biologiske grupper eller samfund; de arter, som tilsammen danner et samfund, har temmelig nøi-

agtig de samme grænser for sin udbredelse. Paa de tre karter (Pl. III—V) er disse samfunds udbredelse fremstillet ved karakteristiske repræsentanter.

Ved karternes konstruktion har jeg foruden mine egne iagttagelser benyttet nogle notiser over plankton paa 74—80° N. br. i begyndelsen af september 1900, som professor Cleve med sin sædvanlige elskværdighed har stillet til min disposition.

Samfundene er:

1. Tripos-Plankton, et samfund af sydlige arter med karakterform *Ceratium tripos* s. str. (*C. tripos v. baltica* Schütt).

   Foruden denne hører hertil ogsaa bl. a. *Ceratium macroceros, bucephalum* og *furca, Peridinium divergens* s. str. og en liden copepode, *Microsetella atlantica.*

   Ceratium fusus ligeledes, men den gaar noget længere mod vest end de øvrige.
2. Longipes-Plankton, et nordligt samfund, karakterform *Ceratium longipes.* Hertil ogsaa bl. a. *Peridinium depressum, ovatum* og *pallidum.*
3. Labradorica-Plankton (arktisk). Karakterform er *Ceratium arcticum.* (= *C. labradoricum* Schütt) og kun meget faa andre organismer. Maaske enkelte større arter som *Clio borealis* bør henregnes hid.

Ved adskillelsen af disse samfund er jeg i alt væsentligt i overensstemmelse med Cleve og Ostenfeld.

Vi vil se lidt nærmere paa karterne; hvert af dem er kun bygget paa forekomsten af en eneste art; men da de til samme samfund hørende arter følger hinanden, vilde et kart for de fleste andre arter næsten falde sammen med et af disse tre.

1. *Ceratium tripos* (Pl. III) tilhører udelukkende den varmeste del af Nordhavet. Den formerer sig rigelig i de vandmasser, som bevæger sig fra Færø-Shetlandsrenden mod nordøst, desuden i Nordsøen, Skagerak, Kattegat og en del af Østersøen, men ingen andre steder. De omtalte vandmasser har en atlantisk karakter, men de er ikke fri for tilblanding af ferskvand fra Nordeuropas kyst, især langs med overfladen. Derfor har man flere beviser. Paa vor reise fra Jan Mayen til Norge fandtes *Ceratium tripos* i mængde første gang paa station 43 (69° 52' N. br., 5° 15' Ø. f. Gr.); samtidig sank saltgehalten i overfladen lidt (fra 35,20 til 35,08 ‰) og temperaturen steg (kfr. pl. I). I planktonprøverne fandtes sammen med de ægte planktonalger løse algetraade fra land (*Ulothrix)* og grund-diatomeer (*Navicula)*; paa overfladen drev endog enkelte løsrevne tangdusker *(Ascophyllum nodosum).* Fra station 43 til den norske kyst (Vesteraalen) beholdt overfladeplanktonet sin karakter uforandret.

De store mængder af Ceratium tripos var indskrænket til et omtrent 200 kvartmile bredt belte parallelt med den norske kyst; den fandtes dog ogsaa, men sparsomt, længer mod vest indtil 2⁰ vest f. Gr., ogsaa her i følge med de samme arter (Ceratium furca &c.). Saltgehalten var her meget høi (35,22), vandmasserne altsaa af ren atlantisk oprindelse.

2. *Ceratium longipes* fandtes sommeren 1900 omtrent over hele Nordhavets overflade (Pl. IV); i den nordvestlige del traadte den tilbage ligeoverfor *C. arcticum*, som beherskede havet omkring Jan Mayen. I den sydøstlige del fandtes *C. longipes* og *C. tripos* sammen, begge arter omtrent lige talrigt. Efter resultatet af tidligere undersøgelser er det ellers regelen, at *Ceratium tripos* om sommeren dominerer langs hele Norges kyst, medens *C. longipes* har sit maksimum i mai—juni, men kun findes sparsomt i juli—august. Dette hænger sandsynligvis sammen med, at sommeren 1900 i Nordhavet var koldere end i de foregaaende aar; planktonets fordeling i juli—august 1900 svarer formentlig til den tilstand, som er at finde i et normalt aar i juni.

   Kartets kurver viser tydelig, at *Ceratium longipes* ikke er at opfatte som en arktisk art. Dens udbredelsescentrum kunde ligge nordenfor Island, som Ostenfeld antager, men snarere er vel den og de andre arter i samme samfund saadanne organismer, som har sit store formeringsomraade næsten over hele Nordhavet, hvor de da alt efter aarstiden snart deler sig livlig og snart igjen aftager i mængde for at overvintre som enkelte spredte individer.

3. *Ceratium arcticum* havde i 1900 udbredt sig over en stor strækning, som kartet viser (pl. V). Denne art dominerer om sommeren i alle vandlag, som har direkte arktisk oprindelse.

   Den trænger frem temmelig langt mod syd, enkelte individer var endog at finde lige paa station 7, ikke langt fra den norske kyst udenfor Stadt. Den østislandske polarstrøm synes at komme meget nær hen til denne del af Norges kyst; om sommeren har jo vandmasserne en helt atlantisk karakter selv temmelig langt fra land, men det er endnu ikke afgjort, om ikke polarstrømmen om vinteren eller vaaren kan bryde igjennem Golfstrømmen, saaledes som O. Pettersson antager.[1])

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[1]) Ved vor undersøgelse af denne strækning i begyndelsen af februar 1901 viste det sig, at varme atlantiske vandmasser var at finde fra Stadt uafbrudt indtil over 220 kvartmile fra land i VNV.lig retning. Hele veien fandtes overveiende sydlige planktonformer (Ceratium tripos &c.), om end sparsomt.

Ceratium arcticum fandtes i smaa mængder udbredt over det samme omraade som om sommeren, altsaa ind til Storeggen. Dette tyder ikke paa, at Petterssons antagelse er rigtig.

Sammenligner man de tre planktonkarter, saa sees det snart, at *Ceratium tripos* og *C. arcticum* omtrent udelukker hinanden; hvor en af disse to begynder at optræde i mængde, der ophører den anden, og omvendt. *C. longipes* forekommer sammen med de to andre, kun ved Islands nordvestkyst har den et omraade, hvor den hersker alene.

I denne foreløbige meddelelse har jeg kun villet fremhæve nogle af de karakteristiske former; ogsaa mange andre organismer kan give vigtige fingerpeg, især naar man ikke alene studerer deres forekomst, men ogsaa deres udviklingsforhold. De sjeldne formers udbredelse har jeg endnu ikke rukket at undersøge.

Det andet hovedøiemed for mine planktonundersøgelser var at faa en oversigt over mængdeforholdene i de forskjellige havomraader og i de forskjellige dybder.

Paa alle stationer blev der derfor indsamlet plankton med dr. Petersens kvantitative lukkehov. Som oftest blev der taget prøver fra følgende dybder: 0—20 m., 20—50 m., 50—100 m., 100—200 m., undertiden ogsaa flere i større dybde. Bearbeidelsen af alle disse indsamlinger er endnu ikke afsluttet. Af hovedresultaterne vil jeg kun fremhæve følgende:

De organismer, som kan danne hovedmassen af planktonet, er især diatomeer, peridineer og krebsdyr (copepoder), især *Calanus finmarchicus*.

Diatomeerne har sit maksimum nær overfladen, de kan findes i mængde indtil omtrent 50 meters dybde; i større dyb findes i almindelighed kun enkelte individer. Peridineerne findes ogsaa i størst mængde i de øvre lag, men kan dog gaa noget dybere end diatomeerne.

Calanus finmarchicus findes over hele Nordhavet; hovedmassen lever i de øvre lag indtil omtrent 100 m. dybde; maksimum er snart nær overfladen, snart mellem 50 og 100 m. under denne. Hvis overfladens plankton bestaar af peridineer, findes *Calanus* gjerne mellem disse; men hvis diatomeerne er i overvægt, søger *Calanus* dybere ned.

De eksemplarer, der fandtes i Nordhavets nordvestlige del, var store og havde en kraftig rød farve; i „Triposregionen“ fandtes kun i dybet enkelte større individer; nær overfladen levede derimod store mængder af mindre eksemplarer, kun halvt saa store og blegere af farve. Jeg vover endnu ikke at afgjøre, om disse smaa er aarets yngel, som i det varme vand har udviklet sig raskt, eller om det er en anden, mindre race.

III.

Fiskeforsøg.

(Af **Johan Hjort.**)

I aarene 1897—1899 udførte jeg i Christianiafjorden en række undersøgelser over forekomsten af yngel af madnyttig fisk. Sammen med hr. K. Dahl, som i Trondhjemsfjorden havde udført lignende studier, offentliggjorde jeg resultaterne af dette arbeide i en afhandling „Fishing experiments in Norwegian Fjords"[1]). I dette arbeide anføres pag. 120 vore hovedresultater at være følgende:

„1. At et stort antal fisk gyder i selve fjordene.
2. At det fundne antal pelagiske æg er lidet. At æggene oftest findes i de første udviklingsstadier, og at larver omtrent aldeles savnes.
3. At aarets yngel af fisk med pelagiske æg ved sommertid kun kan findes ude ved den aabne kyst i mængder; for den sydlige del af landets vedkommende kun vestenfor Lindesnæs, og for den nordlige dels vedkommende kun i øbæltet og ved den aabne kyst . . . .
4. Først sent paa høsten, i oktober, november, ja endnu senere viste der sig, og det pludselig, store mængder af aarets yngel i de fjorde, som vi undersøgte.
5. Ved sommertid fandtes derimod i fjordene store mængder af yngel af de fiske, der lægger sine æg paa bunden.

Det aabenbare misforhold, der saaledes var paavist, mellem den rigere forekomst af ældre stadier af fisk med pelagiske æg og som gyder i fjordene og fjordenes overordentlige fattigdom paa aarets yngel ved sommertid, kan efter vor mening alene forklares derved, at den sterke udadgaaende strøm i gydetiden fjerner de drivende æg fra fjordene og sydkysten og derved forhindrer dem i at blive udklækkede, før de naar ud til kystfarvandet. Aarsyngelens pludselige forekomst i fjordene om høsten maa betragtes som en indvandring."

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[1]) Report on Norwegian Fishery and Marine Investigations. Vol. I. 1900. No. 1. Tidligere udgivet paa norsk „Fiskeforsøg i norske Fjorde". 1899.

Medens alle fisk med pelagiske æg viste denne eiendommelighed. der efter vor mening altsaa skyldes strømmenes rent mekaniske virkning. fandt vi desuden hos de fisk, der har stor svømmedygtighed, som torskearterne, en anden lignende lovmæssighed, idet disse fisk, ogsaa naar de er fuldvoksne, viste sig at foretage aarlige periodiske vandringer ud og ind af fjordene. Dette bevistes, foruden af vore fiskeforsøg, af statistikken over det stedfindende fiskeri i Christianiafjorden. Især er det de store torsk, der kommer ind ved vintertid i fjordene, ligesom jo landets store periodiske fiskerier skyldes den omstændighed, at vældige fiskemasser i gydetiden (maanederne januar—april) nærmer sig kysterne for atter at forsvinde aldeles fra disse.

Det store spørgsmaal, hvor disse fiskemasser vandrer hen, naar de forlader kysterne, lykkedes det os ikke at besvare i ovennævnte afhandling, og havde vi heller ikke stillet os den opgave, idet kun smaa fartøier stod til vor disposition, med hvilke kun indelukte og beskyttede farvand kunde undersøges.

Hos mig var imidlertid alt mere og mere den tanke bleven levende, at flere af de gamle forestillinger om fiskenes vandringer — baade fiskernes og videnskabsmændenes — var i strid med nyere erfaringer.

Paa den ene side var den af de fleste biologer nærede anskuelse, at de pelagiske æg skulde gaa tilgrunde, naar de kom ud over de store havdyb, mig uforstaaelig, og med de erfaringer, jeg ved mine kystundersøgelser havde faaet angaaende havstrømmenes indflydelse paa de drivende æg, reiste det spørgsmaal sig for mig, om ikke millioner af æg ude i verdenshavene maatte udvikle sig og det til sene stadier. **Fiskene** maatte under strømmenes indflydelse nødvendigvis føre en pelagisk eksistents og det gjennem en større del af sit liv. Hr. Dahls og mine forsøg udførtes væsentlig med redskaber, der havde til hensigt at fiske langs bunden, og vore resultater havde derfor nærmest kun bevist, at yngelen af madnyttig fisk ikke findes i fjordene, i vandlagene langs bunden. Vi var ogsaa fuldt opmerksom paa denne vore undersøgelsers begrænsning og siger herom pag. 132: „Den mulighed kan tænkes, at fjordenes fattigdom paa torskeyngel og den pludselige tiltagen i mængde om høsten kan skyldes den omstændighed, at hovedmængden af yngelen indtil den tid har ført en pelagisk tilværelse. Intet positivt vides imidlertid herom og hvad fjordene angaar, er vi ikke tilbøielige til at lægge vegt paa en saadan mulighed.“ Pag. 77 siger jeg: „Det synes mig sandsynligt at antage, at bundtrawlen under udhivingen vilde fange iallefald nogle af de smaa yngel, om disse var tilstede i nogen nævneværdig mængde.“ Jeg anfører der endvidere i et senere arbeide at ville komme tilbage til spørgsmaalet efter at have anvendt nye apparater.

Ogsaa for de ældre stadiers vedkommende reiste det spørgsmaal

sig alt mere for mig, om de ikke kunde foretage vandringer langt ud over de havomraader, der udmerker sig ved forholdsvis ringe dyb. G. O. Sars fremsatte som resultat af sine mangeaarige studier den anskuelse, at de store torskemasser, der om vaaren forlader vore kyster, da vandrer ud paa de udenforliggende kystbanker og spreder sig her. I hans beretning fra den 1ste norske Nordhavsekspedition 1876 udtaler han saaledes, at „al den skrei, som om vinteren staar under kysten, og som er gjenstand for nogle af vore vigtigste fiskerier, den øvrige tid af aaret er fordelt alene over den strækning af havet, hvis bund danner barrieren mod det udenfor liggende ishavsdyb, idet navnlig den yderste grænse af denne barriere ved sit rigt udviklede dyreliv og bundens beskaffenhed danner et bekvemt opholdssted for umaadelige mængder af denne fiskeart.“

I det øiemed at skaffe beviser for denne theori, der i Sars' beretninger ikke er bevist ved anførsel af bestemte fiskeforsøg eller beskrivelse af nogen bestemt fangst, har jeg tidligere hos mange fiskere søgt at erhverve sikre data over, hvor mange torsk de eksempelvis kunde fange paa vore kystbanker om sommeren. Herunder blev jeg imidlertid forbauset ved at erfare, at der paa de mange millioner kroge, der nu ved sommertid under vort livlig opblomstrende bankfiske (ved Aalesund, Vesteraalen) hvert aar sættes om sommeren, kun faaes meget faa torsk. Meget samstemmig har fiskerne saaledes fortalt mig, at de paa mange tusinde kroge satte paa bankerne kun erholder nogle faa (2—10) torsk pr. nat. Kun fra Finmarkens banker og havet mellem Finmarken og Spitzbergen kjender man til, at der findes mængder af torsk om sommeren. Hvor er da vore torskemasser om sommeren, naar de ikke i mængder findes paa kystbankerne?

Saadanne var de spørgsmaal, der var de ledende for „Michael Sars“s fiskeforsøg i det forløbne aar. I følelsen af, at de nævnte spørgsmaal vil tage lang tid til sin løsning, forekom det mig at være rigtigst at begynde med en systematisk undersøgelse af det mest ubekjendte, nemlig havet med de store dybder (over 400 meter), og det pelagiske liv i dette.

Til dette øiemed anvendtes tre slags redskaber[1]) nemlig, 1) store hove, hvoraf en af en diameter af 21 fod med en pose med masker, som de der anvendes ved fangst af ræger, og en af en diameter af 8 fod, og med silkepose, som den der er konstrueret af Hensen og anvendt paa Valdiviaekspeditionen, 2) en pelagisk trawl og 3) flydeliner.

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[1]) En nærmere beskrivelse af disse redskaber vil først gives i den udførlige beretning.

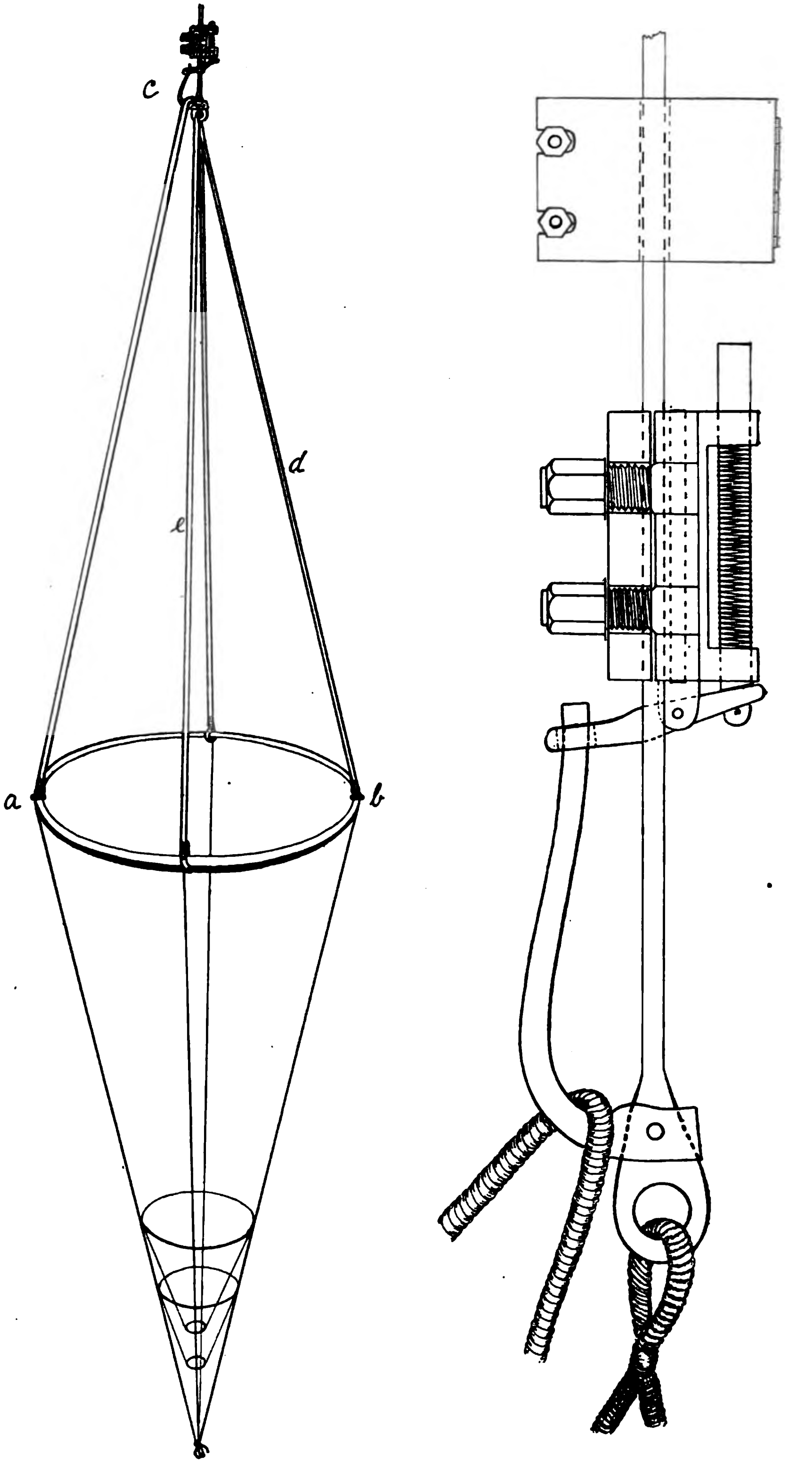

Fig. 5.

Hovene anvendtes dels til vertikalt, dels til horizontalt fiskeri. Under vertikalfiskeri kunde de lukkes ved et slippelod og saaledes gjennemfiske bestemte dyb, under horizontalfiskeri kunde de ved en boje holdes i et bestemt dyb. Fig. 5 illustrerer hoven anvendt som vertikalhov, fig. 6 som horizontalhov, som saadan anvendtes kun den største hov. Ved de to led a og b (se fig. 5) kan de to halvringe let bringes til at falde sammen, saasnart faldvægten bringer krogen c til at falde ud og derved sætter hanefoden d ud af funktion, samtidig med at hele hovens vegt bliver hængende i hanefoden e. Hoven viste sig meget let at manøvrere, naar den kun altid lukkedes, før den toges ombord.

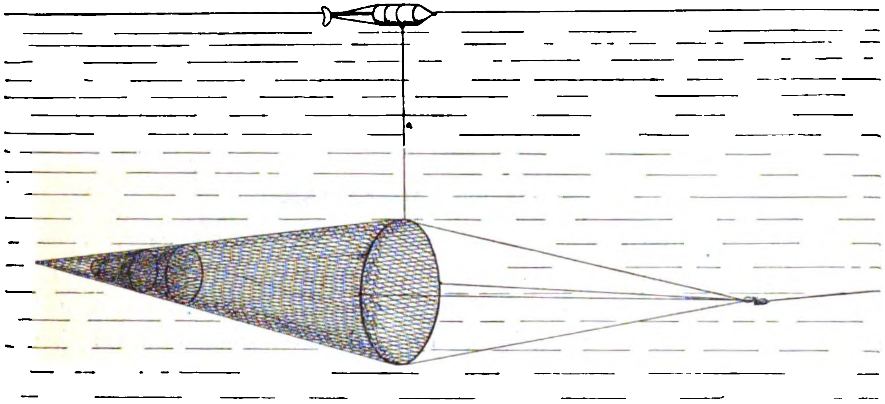
Fig. 6.

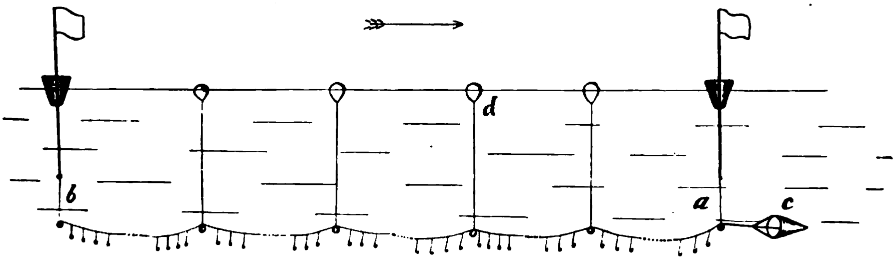

Fig. 7.

Som slæbehov under sagte fart funktionerede den ogsaa udmerket, der var dog herunder saa stor kraft paa den, at leddene maa være meget sterke. Dybden kan ogsaa varieres, dog maa linen a ikke blive for lang, idet den da gjør stor modstand i vandet.

Den pelagiske trawl anvendtes kun lidet og vil blive nærmere udarbeidet under næste togt.

Flydeliner (fig. 7) sattes fra fartøiets agterende under ganske lang-som fart forover. 2 boier (Grimsby, Captain Buoys) sattes for enderne af linen, hver med en line (a og b) af en længde svarende til det dyb, hvori jeg ønskede at fiske. For enden af disse liner en temmelig tung vegt, og ved den ene line et flydeanker (c) af seildug for at holde de to bojer fra hinanden. Mellem begge bojer spændtes derved linen, som endvidere holdtes oppe ved en line med en stor glaskugle eller seildugsboje (d) for hver hundrede kroge. Afstanden mellem krogene var 2 favne. Denne line sattes i regelen, før en undersøgelsesstation toges, dernæst hydrograferedes og toges planktonprøver, og saa blev linen trukken. Linen kunde saaledes staa nogle faa timer; den var i regelen agnet med salt sild eller iset blæksprut.

De med disse redskaber erholdte resultater kan bedst ordnes i 3 grupper, alt efter som de gjælder: Større planktonorganismer, Drivende fiskeyngel eller Større fisk.

I. Større planktonorganismer.

Det rige materiale, som erholdtes af disse organismer, er endnu langtfra bearbeidet og vil først senere saavel i systematisk som i biologisk henseende kunne behandles udførlig. Her skal kun paa grundlag af journalernes notater fra arbeidet ombord omtales endel karakteristiske og vigtige forhold. Medens træk med de store hove i de øvre 200 meter overalt i Nordhavet altid kun gav en fauna hovedsagelig bestaaende af de nogle millimeter store copepoder, blandt hvilke fremforalt masser af *Calanus finmarchicus*, endvidere manæter som *Cyanea capillata* og meduser som *Aglantha digitalis* fandtes der i de større dyb en herifra afvigende og særdeles karakteristisk fauna. Dennes vigtigste former var:

Af encellede organismer kun Radiolarier.

(Smaa krebsdyr)	„ Copepoder:	*Calanus hyperboreus.*
		Euchaeta norvegica.
	„ Amphipoder:	*Euthemisto libellula.*
		Parathemisto oblivia.
		Cyclocaris Guilhelmi.
(Meget lig kril.)	„ Schizopoder:	*Nyctiphanes norvegicus* og flere andre.
(„Ræger“.)	„ Decapoder:	*Pasiphäe tarda.*
		Hymenodora glacialis.
	„ Meduser:	*Atolla verillii.*
		Pectyllis sp.
		Codonium princeps.
(Orme.)	„ Vermes.	Flere arter Sagitter, hvoraf 1 talrig art af indtil 10—11 cm.s længde og staaende meget nær *Sagitta lyra.*
	„ Blæksprutter.	*Gonatus Fabricii* og en Cirrhoteuthisart.

Af Fiske. Scopelider af forskjellige aldersstadier (voksne 5—6 cm. lange).

Som eksempler paa fangsterne med Hensens hov i det aabne Nordhav kan anføres:

Station 10. 28de juli.

1ste træk 0—200 m. Næsten udelukkende *Calanus finmarchicus*, smaa individer af *Parathemisto* og *Boreophausia*.

2det træk 250—400 m. Kun nogle faa *Calanus finmarchicus*; talrige *Calanus hyperboreus*, *Euchaeta norvegica*, store *Parathemisto oblivia*, *Nyctiphanes norvegicus*, *Sagitta* sp., store eksemplarer.

Station 34. 10de august.

1ste træk, Hensens hov 0—150 m. Ca. 1 liter *Calanus finmarchicus*, nogle faa smaa *Sagitta*, unger af *Parathemisto*, nogle faa *Aglantha*. .

2det træk, 500—1000 m. Store sterkt røde *Euchaeta norvegica*, *Calanus hyperboreus*, annelidelarver, *Parathemisto oblivia*, *Cyclocaris Guilhelmi*, *Hymenodora glacialis* (nogle faa store og mange smaa), *Sagitta* to store arter. En stor ostracode, radiolarier.

Station 46. 13de august.

Flere træk med dr. Petersens lukkehov indtil 200 m. Næsten kun *Calanus finmarchicus*.

2 træk 0—950 m. med den største hov. Store røde *Euchaeta*, talrige *Pasiphäe tarda*, store *Sagitta*, *Hymenodora glacialis*, *Nyctiphanes*, pragtfuldt farvede meduser som *Atolla verilli* 7 scopelider, 1 blæksprut, store *Sagitta*.

Station 67. 1 træk med dr. Petersens lukkehov i 1000—1500 m. 3 store *Sagitta*. Nogle faa *Calanus finmarchicus* og *hyperboreus* (store individer), 1 *Ephauside*, *Ostracode* og *Cyclocaris Guilhelmi*. Ingen diatoméer.

Disse eksempler vil formentlig antyde de store hovedtræk i denne karakteristiske pelagiske fauna, der i bestemt dyb svæver under den ensformige næsten kun af vegetabilske former og *Calanus finmarchicus* bestaaende fauna i de øverste 200 meter.

2. Drivende fiskeyngel.

Det var oprindelig min hensigt at lede efter yngel med vertikalhove, en hensigt, hvori jeg blev bestyrket derved, at der paa vestlandet fiskes meget „smaamort“ i „glibe“ og at det før afreisen fra Aalesund den 19de juli i et vertikaltræk med Hensens hov lykkedes mig at fange en liden torskeunge ca. 3 cm. lang i Sulefjorden ved Aalesund. Under overfarten fra Aalesund til Island forsøgtes derfor vertikaltræk med alle hove uden nogen fangst af yngel. Min tro paa yngelens pelagiske udbredelse blev imidlertid paa denne reise alligevel bestyrket derved, at vi gjentagende i ventrikelen af de os stadig omkredsende maager (*Rissa tridactyla*) fandt hvirvler af fiskeyngel. Paa station 9 erholdt vi desuden yngel (af 14 cm. længde) af en torskeart, *Gadus poutassou* saavel i pelagisk trawl som i ventrikelen af torsk fangne dersteds. Da jeg endvidere nord for Island paa station 11 paany fik 3 smaa hyse i Hensens hov, bestemte jeg mig til at risikere at slæbe den store hov, hvilket jeg havde frygtet af hensyn til det sterke tryk, der vilde komme paa den. Forsøget lykkedes straks, i det 15 minuters slæbning paa station 12 gav 109 yngel af torsk, nemlig 61 torsk af en størrelse mellem 2,4 og 4,5 cm. og 48 hyse af 3,2—5,5 cm. Hermed var yngelens pelagiske levevis bevist og methoden for fangsten given, og jeg søgte under togtets videre forløb systematisk et kartlægge yngelens udbredelse i Nordhavet derved, at der blev fisket paa hver station med slæbehov.

Betragter man hosstaaende kart no. VI over yngelens udbredelse, vil man se, at denne er særdeles vidstrakt. Indtil 240 mil (mil = $1/_{60}{}^{0}$) fra den norske kyst og lige indtil land var overalt yngel af torskearterne at finde. Yngelens forekomst var desuden overordentlig karakteristisk og overensstemmende med andre vel karakteriserede forhold. Sammenligner man saaledes kartet over yngelens udbredelse i Nordhavet med de hydrografiske karter, vil man se, at kurverne for yngelens udbredelse falder sammen med kurven for 35,1 ‰ saltholdighed, det vil sige det atlanterhavsvand, der har modtaget nogen tilblanding af vand fra kontinentet og ikke helt holder det rene atlantiske vands høie saltmængde af over 35,25 ‰. Høist overensstemmende er ogsaa yngelens udbredelse med de øvrige planktonformers. I de vandlag, der huser rent oceaniske eller arktiske former, saasom de mægtige lag mellem Island og Jan Mayen eller rundt Beeren Eiland, fandtes ingen drivende yngel af torskearterne. Disses forekomst var saaledes helt knyttet til de lag, hvis saltholdighed og sydlige plankton tyder paa, at de har været i berøring med kysterne. Under reisen fra Jan Mayen til Norge optraadte saaledes med en skarp overgang paa en gang alle disse kystformer, som omtales af hr. Gran som stemmende med Nordsøens og kystfarvandets plankton, endvidere manæter, *Cyanea capillata*, hvis forekomst i de oceaniske eller arktiske vandlag ikke kunde paavises. Alt dette tyder paa, at yngelen er kommen drivende fra kysterne, hvad jeg ogsaa anser sandsynlig af den grund, at hr. Wollebæk i begyndelsen af mai maaned paa krydseren „Heimdal“ overfor den største del af Nordhavet og fiskede med hove efter drivende æg uden at kunne paavise saadanne i stor afstand fra kysterne. Dette spørgsmaal vil dog blive optaget til videre undersøgelse under kommende togt. Saafremt min foreløbige slutning, at det aabne Nordhavs yngel er gydt inde ved kysterne, Nordsøens eller Nordhavets, viser sig rigtig, vil man formentlig i studiet af disse drivende yngel ligesom i studiet af manæternes udbredelse have et nyt og udmerket middel til at studere hastigheden af disse vandlags bevægelser, som under sin vei berører kysterne og senere breder sig over Nordhavet.

Med hensyn paa yngelens kvantitative udbredelse over Nordhavet vover jeg endnu ikke at give nogen sikre data; jeg tror dog, at det i fremtiden ikke vil vise sig umuligt at erholde en kvantitativ forestilling over det aabne Nordhavs mængde af drivende yngel. Jeg har nemlig ikke indtrykket af, at yngelen i juli-august og endmindre tidligere har begyndt at vandre synderlig i stimer, som f. eks. sildens yngel jo gjør. Vi fangede yngelen altid sammen med flere eller færre brændemanæter, *Cyanea capillata*, og om jeg end tror, at Sars's bekjendte lære om et slags symbiotisk forhold mellem yngelen og manæterne ialfald er noget overdreven, og at yngelens levevis sammen med manæterne heller bør forstaaes saadan, at begge dyreformer som fødte ved kysterne og lidet svømmedygtige er afhængige af de samme eksistentsbetingelser (strømmen), saa tyder dog alle iagttagelser af torskeungerne i den alder fra kysterne paa, at de holder sig forholdsvis stille ligesom svævende paa et begrænset omraade, ofte i nærheden af manæterne og ikke samler sig i stimer, der aktivt foretager lange vandringer. Af hensyn til yngelens levevis tror jeg derfor ikke, at der vil være nogen hindring for senere at udarbeide en methode, der vil kunne give en kvantitativ forestilling af yngelens udbredelse i et bestemt farvand. Imidlertid tror jeg ikke, at de af mig udførte træk og de dermed erholdte tal kan tjene som grundlag for en saadan kvantitativ forstaaelse og det bl. a. af den grund, at den store hov trods sin dybde af 21 fod (7 meter) dog ikke gjennemfiskede vandet i hele den dybde, hvori yngelen maa antages at forekomme. Først anvendte jeg nemlig hoven uden boje, og jeg antager, at den da gik flere favne under overfladen, og den store mængde af yngel, som da fangedes, gjør det utvivlsomt, at den ikke alene er fanget under den korte indhiving, men ogsaa under slæbningen fremad. Senere, da boje sattes paa hoven, og denne holdtes lige i overfladen, erholdtes ogsaa mængder af yngel. Skal der udarbeides en kvantitativ methode, maa der først konstateres, indtil hvilket dyb yngelen findes, og hertil maa methoden tage hensyn. Nogen vanskelighed ved bedømmelsen af længden af den gjennemfiskede strækning vil der vistnok ikke foreligge indenfor de grænser for nøiagtighed, som man overhovedet bør tilstræbe ved alle denslags biologiske kvantitetsbestemmelser. Trods at de paa togtet erholdte tal over yngelens forekomst saaledes kun kan give et meget utilfredsstillende indtryk over mængden paa de forskjellige lokaliteter, og mine træk jo væsentlig kun havde til hensigt at konstatere, om yngel overhovedet var tilstede eller ikke, vil jeg dog her alligevel anføre endel eksempler paa, hvad hoven kunde fange:

A. Rundt Island.

Station 12. 30te juli. 2 mil nord af Island. 15 minutters slæbning i nogle favnes dyb. Fangst 109 yngel af torskearter, hvoriblandt 61 torsk af 2,4—4,5 cm. længde og 48 hyse 3,2—5,5.

Station 12. 3die august. Nær Grønlandsisen. 30 minutters slæbning i nogle favnes dyb. 15 yngel af torskearter.

Station 14. 4de august. I Irmingerstrømmen. Et træk gav kun 2 manæter, skjønt masser i overfladen (hoven nogle favne dybt) og 128 yngel af torskearter, hvoriblandt 104 hyse af 3,3—7,3 cm. længde og 24 torsk af 4,2—5,2 cm. Desuden masser af yngel af lodde.

B. Havet mellem Jan Mayen og Norge.

Station 43. 11te august. 1 times træk i overfladen. 8—10 manæter (*Cyanea capillata*), 51 torskeyngel fra 5,1—7,4 cm.

Station 44. 12te august. 1 times træk i overfladen. 2 yngel af kolje af 7,7 cm. længde.

Station 45. 12te august. 1 times træk i overfladen. 23 yngel af torskearter, hvoriblandt 11 kolje 6,6—9,6 cm. og 12 torsk 5,1—6,6.

Station 46. 13de august. 1 times træk i overfladen. 8 kolje 7,7—10,8 cm.

En voksen sei fanget paa line havde i ventrikelen 25 yngel af torskearter, hvoraf flere kjendelige som torskeyngel.

Station 47. 14de august. 1 times træk i overfladen. 7 kolje af 7,9—9 cm. 7 torsk af 5,1—6,4 cm.

C. Havet mellem Beeren Eiland og Norge.

Station 56. 2 torske 5,5 og 6,2 cm., 1 kolje 7,5 cm.

Station 57. 1 træk i overfladen. 16 torsk 3,8—8,5 cm. 1 kolje 10,7 cm.

1 træk 10—20 favne dybt: 8 torsk 4,5—7,5 cm.

Station 59. 3 torskeyngel.

Station 62. 5 —„—

Station 63. 1 træk. 1 time. 69 torsk 5,2—9 cm., 2 sei 5,7 og 11,5 cm.

Station 65. 1 træk. 1 time. 3 torsk 7,7—8 ctm. 1 kolje 11,3 cmt.

I havet mellem Island og Jan Mayen og fra Jan Mayen til station 43 gjordes mange træk uden fangst af torskeyngel, ligesaa rundt Beeren Eiland.

Fangsten var i disse træk væsentlig. den bekjendte vingesnegl *Clio borealis*, og smaa krebsdyr som mysider, amfipoder, samt meduser og yngel af arktiske fiske, forhold som det vilde føre for langt at berøre i denne foreløbige meddelelse.[1])

De ovenfor anførte tal vidner om, at det aabne hav ved sommertid indeholder store masser drivende yngel, hvilket bliver særdeles slaaende, naar man er opmerksom paa, at yngelen forekommer ned til flere favnes dyb, og at en eneste sei derude kan have 25 yngel i sin ventrikel.

Dette resultat henledede naturlig min opmerksomhed paa to vigtige opgaver, den ene med de nye methoder at sammenligne de i landet dybt indskjærende fjordes yngelmængde med det aabne havs, og den anden at give svar paa det spørgsmaal: Hvor blir der af den store mængde pelagiske yngel i det aabne hav; kommer de ind til kysterne og vokser de op der, eller udvikler de sig videre i det aabne hav, eller gaar de tilgrunde? Det er naturligt, at det paa mit første togt kun lykkedes mig at give faa bidrag til besvarelsen af alle disse mange spørgsmaal, som vistnok vil kræve mange og lange undersøgelser. Jeg vil dog i korthed allerede nu meddele, hvad jeg hidtil har beviser for.

Fjordenes pelagiske yngel. Ovenfor er nævnt, at mine tidligere undersøgelser med bundredskaber i Kristianiafjorden havde ført mig til den antagelse, at de pelagiske æg om vaaren drev ud af fjorden saaledes, at denne ved sommertid saagodtsom var blottet for yngel af fisk med pelagiske æg. Skjønt jeg antog, at mine tidligere trawlforsøg ogsaa antydede, at ingen nævneværdige mængder af pelagisk yngel kunde være tilstede i fjordene, gjorde jeg dog for at klargjøre dette end tydeligere endel undersøgelser af Kristianiafjorden og andre fjorde med den store pelagiske hov. Jeg anfører her endel træk.

Station 75. Skagerak. Flere mil syd af Svenør. 8de oktober. 1 træk med den store hov. 1 time. 70 yngel af hvitting, 2 hestmakrel. Masser af *Cyanea capillata* (brændemanæter).

Station 76. Ved Kristianiafjordens munding. 1 træk. 1 time: 20 hvitting 4,5—14 cm., 1 *Gadus poutassou* (en arktisk torsk) 12 cm., 3 *Caraux trachurus* (hestmakrel) 4—5,3 cm.

Station 77. I fjordens ydre parti mellem Horten og Filtvedt. 1 træk med stor hov. 1 time. 5 hvitting 4,5—9,5 cm.

Station 78. Fjordens inderste del ved Steilene. 1 times træk.
1 yngel af hvitting.
1 nyt træk: ingen yngel.

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[1]) Af stor interesse var det ved Bjørneøen iaar at finde, at al fisk var fuldstændig forsvundet fra øens nærhed. hvilket maa skyldes den særdeles lave temperatur $\div 1^0.5$. I tidligere aar, som f. eks. i 1878 har temperaturen der været mellem $+ 2^0$ og $+ 3^0$, og der har da været meget fisk tilstede.

Som man ser, er der selv saa sent paa aaret som i begyndelsen af oktober en overordentlig aftagen af yngelmængden ind over fjorden, et forhold, som formentlig er end mere udpræget i den egentlige sommertid. I sidste halvdel af oktober viste vore tidligere træk med bundvad pludselig mængder af yngel, som da var kommet ind i fjorden.

Undersøgelser af andre fjorde gav lignende resultater, saaledes gav 2 træk i Trondhjemsfjorden ingen yngel, medens endel træk i de mere aabne havarme: Vestfjorden, Ofotenfjord og Porsangerfjord gav nogle faa yngel i hvert træk.

Sammenholder man saaledes de tidligere aars og den forløbne sommers resultater, kan man nu udtale, at yngelen af torskearterne ved sommertid findes pelagisk i det aabne Skagerak, Nordsøen og det norske Nordhav samt langs stranden ved den yderste havkyst, medens de dybt ind i landet skjærende fjordarme saagodtsom alle er blottede for aarets yngel, der mekanisk føres afsted af havstrømmene.

Hvor blir der af den i det aabne hav omdrivende yngel?

Til besvarelse af dette vigtige spørgsmaal kan jeg foreløbig kun meddele følgende:

1. Ind i de fjorde, som om sommeren maa siges at være blottede for yngel, kommer der om høsten store masser, saaledes at man der, hvor der tidligere i mange vadtræk tilsammen kun har været en enkelt yngel at finde, pludselig kan faaes over 100 pr. træk. Se herom de talrige tidligere erfaringer publicerede i ovenævnte „Fiskeforsøg i norske Fjorde“. Samtidig med denne indvandring af yngel sker der en almindelig kjendt indvandring af manæter (*Cyanea capillata*) mod kysterne, saaledes at der især ved den ydre skjærgaard kan ligge millioner opkastede paa stranden, og at alle havbugter og sund kan fyldes af dem. De talrige hydrografiske undersøgelser, som til forskjellige aarstider er udført i Skagerak, tyder ogsaa paa en indvandring af vandlag mod kysterne om høsten. Hvad Nordhavet angaar, saa er dettes hydrografi ved høsttid endnu ubekjendt, og det er at vente, at fremtiden vil kaste andet lys over dets vandmassers bevægelser.

2. Der foreligger ved siden af disse erfaringer om yngelens indvandringer mod kysterne ogsaa endel erfaringer for, at de ogsaa kan vokse op til senere stadier (ældre aargange) ude i det aabne hav. Jeg har i det forløbne aar faaet ikke faa beviser herfor.

I de første dage at november foretoges endel drivgarnsforsøg efter sild i Skagerak og herunder fangedes næsten hver nat paa garnene hvitting (*Gadus merlangus*) af anden eller tredie aargang (20,5—30 cm. længde) paa garnene, skjønt disse sattes nogle faa favne fra overfladen, og bundens dybde var indtil 350 favne. (Paa station 9 fangedes

ogsaa flere eksemplarer af *Gadus poutassou* af en størrelse af 14—15 cm. (25de—26de juli). Denne fisks vækstforhold er mig dog ikke saa bekjendt, at jeg kan afgjøre, om de er af aarets yngel eller ikke. Jeg har heller ikke i litteraturen fundet noget herom.

Medens det ovennævnte saaledes tyder paa, at baade en indvandring af den pelagiske yngel mod kysterne og en opvækst i dybe og store havomraader kan finde sted, er det fremtiden forbeholdt at afgjøre, hvilken betydning hvert af disse fænomener har, og i hvilket forhold de staar til hinanden. Ligesaa er tilfældet med spørgsmaalet om, i hvilken mængde den pelagiske yngel gaar tilgrunde. Ishavsskippere har meddelt mig, at der i visse aar om sommeren findes tusinder af døde smaafisk langs iskanten, og det falder vanskeligt at tænke sig, at disse smaafisk skulde være andet end drivende yngel, saameget mere som fangstskipperne meget godt kjender lodden (*Mallotus villosus*).

3. Større fiske.

Foruden disse yngre aargange af torskearterne fangedes ogsaa paa togtet i det aabne hav og langt fra bunden voknse fisk, nemlig dels torskearter, dels rødfisk, uer *Sebastes marinus*. Om disse har jeg den forestilling, at de biologisk seet bør henføres til 2 forskjellige grupper nemlig 1) de stationært i det midtre lag levende fiske (rødfisken) og 2) de i de midtre lag *vandrende* fiske (torskearterne).

1. Rødfisken Den første norske nordhavsekspedition fandt i havet mellem Jan Mayen og Norge yngel af uer saa smaa, at det maa sluttes, at den nylig var født der; senere fandt Nansen i maverne af klapmydsen paa isen i havet NV. for Jan Mayen store uer. Af disse meddelelser drog jeg den slutning, at fisken maatte forefindes i de midtre lag i havet og satte mine flydeliner i de dyb, i hvilke ueren fortrinsvis fiskes langs land (i dyb større end 80—100 favne). Overalt, hvor saadanne forsøg gjordes, fandtes ogsaa uer tildels i større mængder, hvad der var saa meget mere forbausende, som vor agn desværre maa siges at have været mangelfuld. Eksempelvis kan anføres:

   Station 43. 11te august. Lodskud over 3000 meter. 400 kroge i 200 meters dyb. 9 uer 41—51 cm.

   Station 46. 13de august. Lodskud over 3000 meter. 800 kroge i 200—400 meters dyb. 1 uer.

   Station 66. 7de september. Lodskud 1967 meter. 400 kroge i 100 meters dyb. 4 uer.

   Station 67. 7de september. Lodskud 2538 meter. 600 kroge i 200 meters dyb. 65 uer af 36 til 47 cm. længde.

   Station 68. 8de september. Lodskud over 3000 meter. 400 kroge i 200 meters dyb. 30 uer af samme størrelse.

Jeg anser det utvivlsomt, at fremtidige undersøgelser med bedre agn og med bedre kjendskab til den rette dybde, hvori linerne bør staa, vil konstatere en endnu langt større mængde fisk i disse dyb, og hermed er formentlig det første bevis leveret for tilstedeværelsen af en rig fiskefauna, bestaaende af store madnyttige fisk, der svæver i et bestemt dyb fra overfladen flere tusinde meter fra havets bund og formentlig tilbringer hele sit liv paa dette sted. Jeg skal senere komme tilbage til betydningen af dette fund.

2. Torskearterne. Det maa desværre indrømmes, at vor agn var lidet egnet til fangst af disse dyr. Naar det alligevel lykkedes at fange saadanne fisk under lignende forhold som skildret for uerens vedkommende, saa føler jeg mig vis paa, at disse fiske i store mængder vandrer ud over de store dyb.

Paa station 9, lodskud 1962 meter, erholdtes paa drivgarn, satte 20 meter fra overfladen, foruden 365 sild, 1 torsk 90 cm. lang.

Paa pilk toges sammesteds i 30 meters dyb 1 sei, i 40 meters dyb 1 torsk 94 cm. lang, paa 400 kroge, som sattes 30 meter under overfladen toges 1 sei 100 cm. lang, 2 torske 84 og 94 cm. lange.

Paa station 10, lodskud 640 meter, sattes 400 kroge ca. 60 meter fra overfladen, toges 11 sei fra 93 til 105 ctm. lange og 1 kolje 75 cm. lang.

Paa station 46, lodskud over 3000 meter toges 1 sei nær overfladen.

Senere sattes linerne væsentlig efter uer og i det dyb (ca. 200 meter) erholdtes ingen torsk. Jeg har adspurgt talrige fiskere og bottlenosefangere, om de ikke har gjort lignende erfaringer, og har herved af dem erholdt den meddelelse, at de paa det saakaldte bottlenosefelt (havet mellem 63° og 68° nord og mellem 5° og 10° vest) ofte kan fiske torsk og sei i de øvre vandlag; ligeledes ved særdeles paalidelige førere af drivgarnsdampere at fortælle, at de under drivgarnsfiske efter sild flere mil vestenfor Stadt, hvor der er flere hundrede favnes dyb, paa sine sildegarn trods de smaa masker og at garnene kun staar nogle favne fra overfladen i januar maaned, naar indsiget af den gydefærdige torsk ventes, kan faa op til 40 saadanne paa en eneste nat.

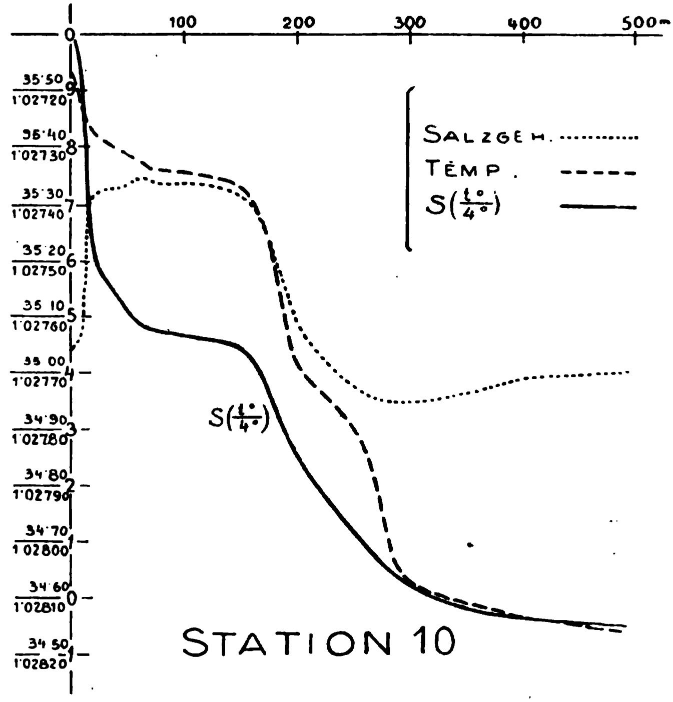
Torskearterne kan saaledes foretage store vandringer uden hensyn til bundforholdene i de store have. Hvorvidt disse vandringer er aktive eller passive ved vandlagenes bevægelser, vil først kunne drøftes, naar Nordhavets hydrografi er ganske anderledes kjendt end hidtil, og bør man lade enhver spekulation herover bero, indtil de kommende aar forhaabentlig har givet os et nyt og rigt materiale til spørgsmaalets belysning. „Michael Sars“ vil i aaret 1901 lægge sit hovedsagelige arbeide paa løsningen af disse spørgsmaal.

At den pelagiske levevis spiller en langt større rolle for en mængde organismer, end man tidligere har antaget, har jeg efterhaanden faaet en mængde beviser for. Se f. eks., hvad derom er anført i „Fishing Experiments“ pag. 83—84. Endvidere henleder jeg opmerksomheden paa det store blæksprutfiske, som ved høsttid foregaar i norske fjorde, da der midt i vandet med krog (haandsnøre uden agn) fiskes hundreder af tønder „Akker“ (*Ommatostrephes todarus*) til agn for fiskerierne. Saadanne store fænomener tillader visnok ogsaa den slutning, at fiskene vandrer paa lignende maade som blæksprutens. En af de mest paafaldende eksempler af mine iagttagelser var det for mig at finde mængder af 5—6 cm. store krabber, en *Portunus*-art siddende paa drivgarnene i Skagerak under de fangstforsøg efter sild, som jeg der anstillede sidst november maaned, og det 28—30 mil af land. Dette viste sig ogsaa at være drivgarnsfiskerne almindelig bekjendt, da de direkte blev adspurgte derom, og det ikke alene Skageraksfiskere, men ogsaa fiskere fra Romsdalen og vestlandet.

Jeg ønsker ikke at forlade de her skildrede fænomener uden i al korthed dertil at knytte nogle theoretiske bemerkninger.

Hvad den praktiske rækkevidde af de gjorte iagttagelser angaar, kan først fremhæves den betydning det har for kundskaben om og lovgivningen for fiskeri efter torskearterne, at man ved, at disse fisk paa forskjellige alderstrin af sit liv færdes over saa store havstrækninger. Medens herved paa den ene side haabet om „fiskekultur“ for disse arters vedkommende i en overskuelig fremtid blir illusorisk, vækkes samtidig forvisningen om havets rigdom paa disse fisk og tilliden til de stedfindende fiskeriers fremtid. Se herom, hvad der udførlig er fremholdt i den oftere omtalte afhandling „Fiskeforsøg“, hvis synspunkter har erholdt en væsentlig bekræftelse. Dernæst bør spørgsmaalet, om der kan drives pelagisk fiskeri i det norske Nordhav, optages til overveielse og fremtidige undersøgelser. Paa station 9 fiskedes 1 tønde sild, skjønt mine sildegarn havde for stor maskevidde for den der forekommende slags sild. Hr. W. Fries af Aalesund har meddelt mig særdeles interessante forsøg, som han nogen tid senere gjorde noget sydligere end vore stationer 8 og 7. Han fik her adskillig sild, saa der kan siges at have været sild næsten helt fra Norge til Island i juli til august 1900.

Et rigt felt for fremtidige studier over de biologiske eksistentsbetingelser i havet byder de fundne forhold i de nordiske have. Ligesom havbunden mekanisk samler op de stadig synkende organismer og organiske rester og saaledes muliggjør et rigere dyreliv i det vandlag, der er bunden nærmest, end i de midtre lag, saaledes antager jeg, at



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35·10 / 1·02760 5
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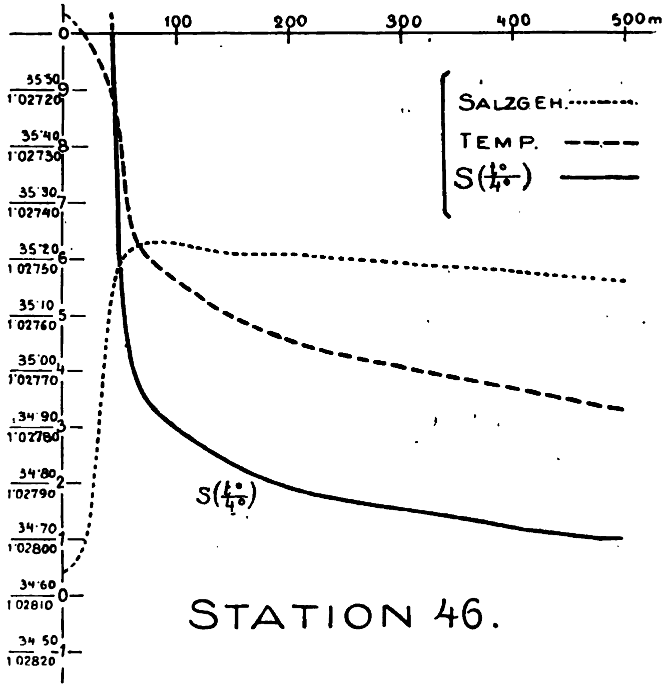
34·90 / 1·02780 3
34·80 / 1·02790 2
34·70 / 1·02800 1
34·60 / 1·02810 0
34·50 / 1·02820 -1
Salzgeh. ....
Temp. - - - - -
S(t°/4°) ———
S(t°/4°)
STATION 10

Fig. 8.



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35·40 / 1·02730 8
35·30 / 1·02740 7
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35·00 / 1·02770 4
34·90 / 1·02780 3
34·80 / 1·02790 2
34·70 / 1·02800 1
34·60 / 1·02810 0
34·50 / 1·02820 -1
Salzgeh. ....
Temp. - - - - -
S(t°/4°) ———
S(t°/4°)
STATION 46.

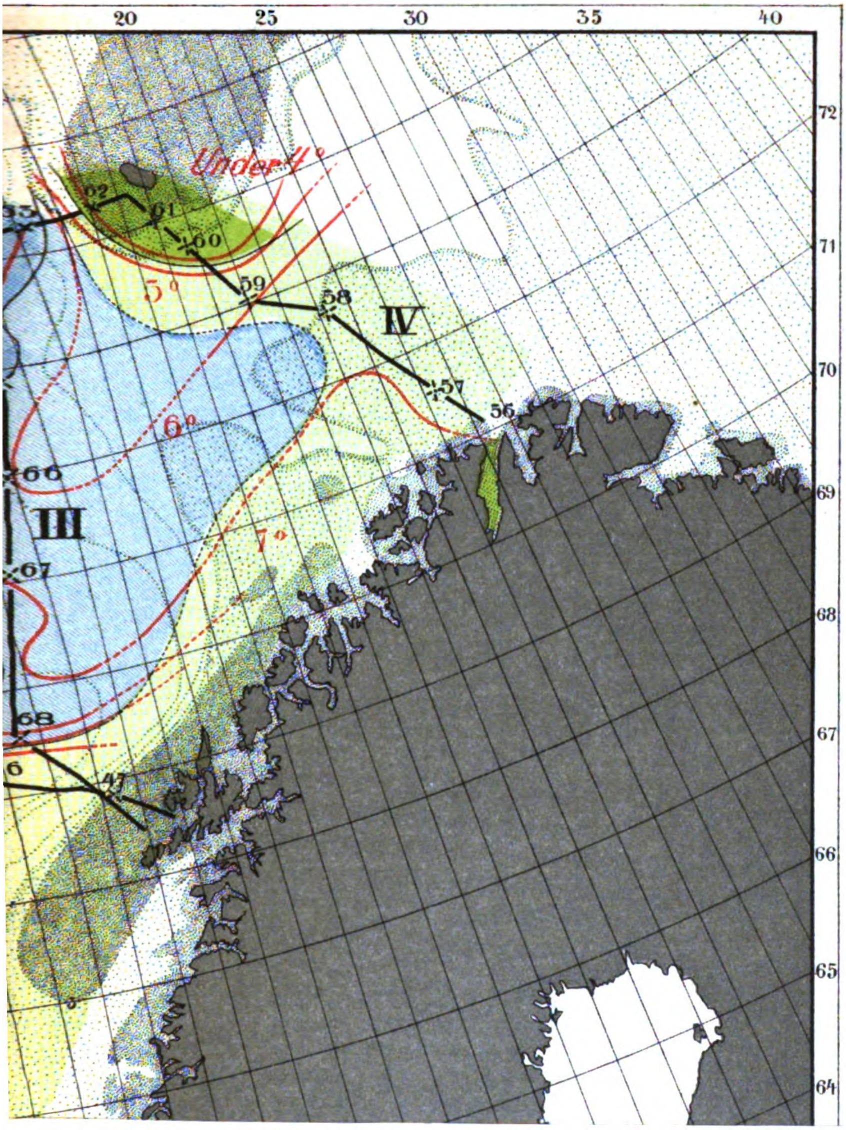
Fig. 9.

midt i havet — i forskjellige dyb alt efter de forskjellige steder og aarstider — dannes lignende ansamlinger af rigere næringsmateriale, hvor en stigning af den specifike vegt bringer de synkende organiske bestanddele til at stanse eller sagtne i sin fart og derved ligesom danner en kunstig bund i havet. De to figurer 8 og 9 viser den specifike vegt („tætheden“) paa de to stationer 46 og 10, som turde være typiske for forholdene i Nordhavet. Station 46 mere i Atlanterhavsvandets midte, station 10 ved Irmingerstrømmen i overfladen, polarstrømmen i dybet. Paa station 10 sees der at være en særdeles skarp grænse mellem de to strømme, paa station 46 er der mere en jevn stigning mod dybet. Paa flere stationer er stigningen i specifik vegt mest udpræget netop paa det dyb, hvor en udpræget rig dybhavsfauna viste sig at være tilstede (i ca. 200 meters dyb). Under næste togt vil der paa basis af de nu gjorte erfaringer blive taget en række prøver fra forskjellige dyb til nærmere konstatering af planktonets kvantitet i disse dyb.

Saafremt det skulde vise sig at være saa, at det er den specifike vegtsforskjel mellem forskjellige lag i havet, som muliggjør eksistentsen af en intermediær fauna, saa skulde man deraf paa forhaand være fristet til at antage den arbeidshypothese, at det især var de egne af havet, hvor arktiske og antarktiske kolde og ferskere strømme mødte varmere og saltere strømme, at saadanne skarpe grænselag kunde opstaa og dermed ogsaa faunaen. Maaske er dette forhold et af de momenter, der bidrager mest til de nordlige kysthaves rigdom paa fisk, idet fiskene i de nordlige have kan vandre langt udenfor kystbankerne. Af enorm interesse vilde det være at faa de antarktiske egne undersøgt med de i denne opsats nævnte methoder, og da fremforalt de egne, hvor varme og kolde vandlag støder mod hinanden. Speciel interesse knytter sig til disse egne af den grund, at her saagodtsom intet land og ingen kystbanker findes, saa man her eventuelt vil staa overfor en ren pelagisk fauna, hvis tilstedeværelse utvivlsomt vilde kaste særdeles rigt lys over fiskenes og de høiere invertebraters levevis i det hele. Det har været mig en stor glæde, at de to store sydpolekspeditioner, den tyske og den engelske, som i aaret 1901 vil undersøge de sydlige have, har antaget mit forslag at optage disse undersøgelser paa sit program; og vil den havforskning, som fortrinsvis interesserer sig for havets økonomi og biologi, med spænding imødese disse ekspeditioners resultater.

Hvad de tropiske farvand angaar, formaar man derom for tiden neppe at gjøre sig nogen forestilling. Saavidt man kan dømme af de hidtil spredte — med meget primitive midler — gjorte indsamlinger (som f. eks. Kjøbenhavnermuseets samlinger af pelagiske fiskeunger publicerede i „Spolia atlantica“), findes der i de varmere egne væsentlig kun de bekjendte pelagiske fisk, der lever i de øverste overfladelag (flyvefisk, makrelarter etc. etc.) Hvorvidt der ogsaa her, maaske i væsentlig større dyb end i de nordlige have skulde findes en rig intermediær fauna, synes mig at maatte være en særdeles taknemmelig opgave at løse for en ny dybhavsekspedition.

Pl. I.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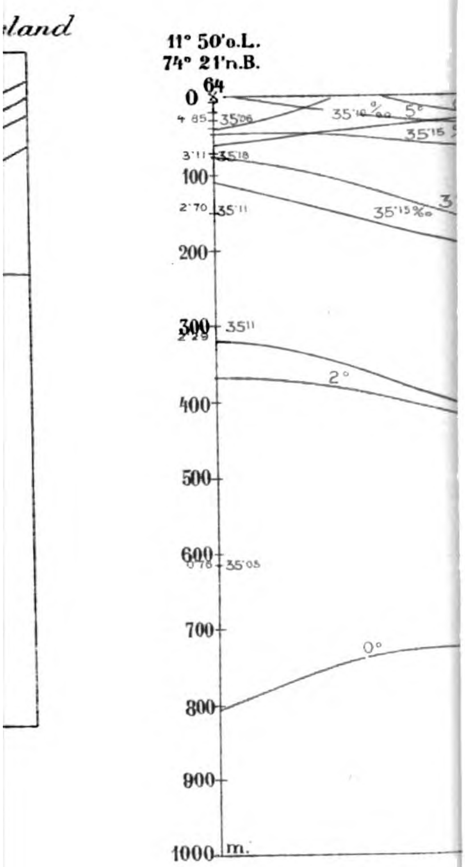
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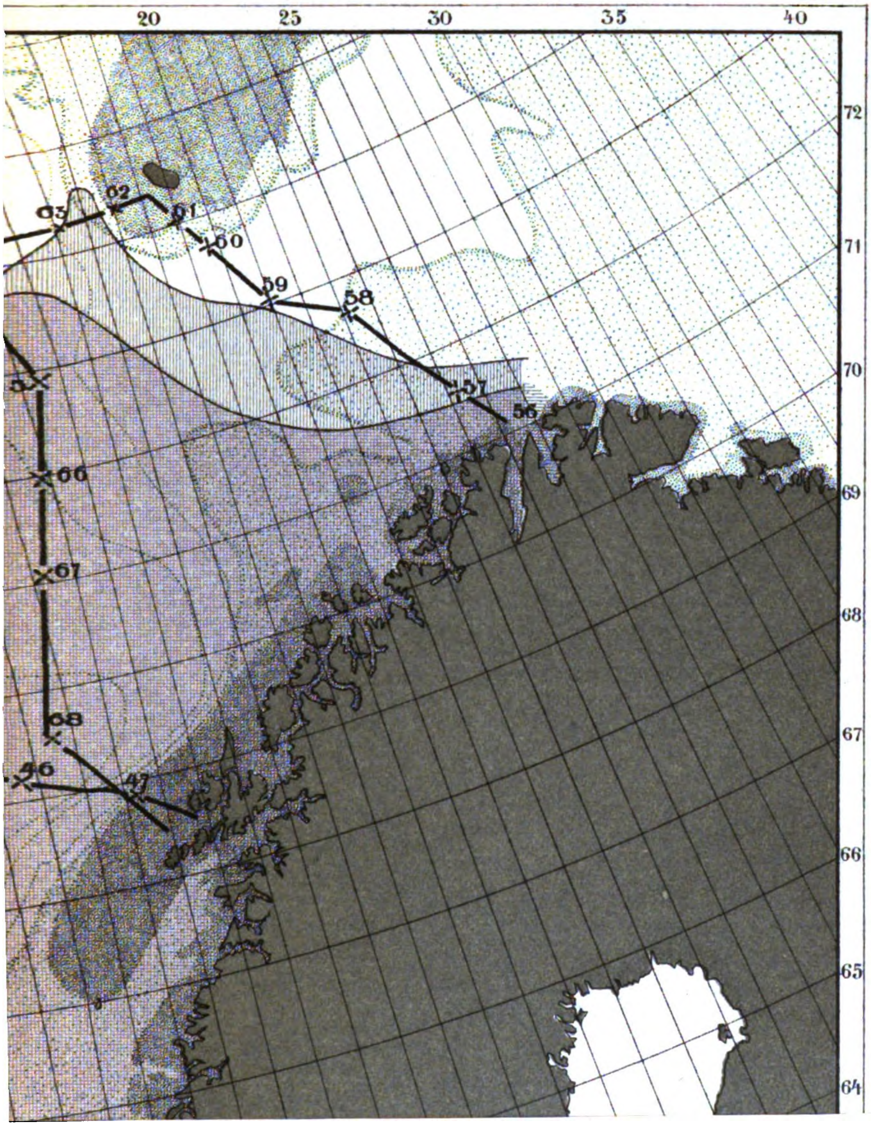
Pl. III.



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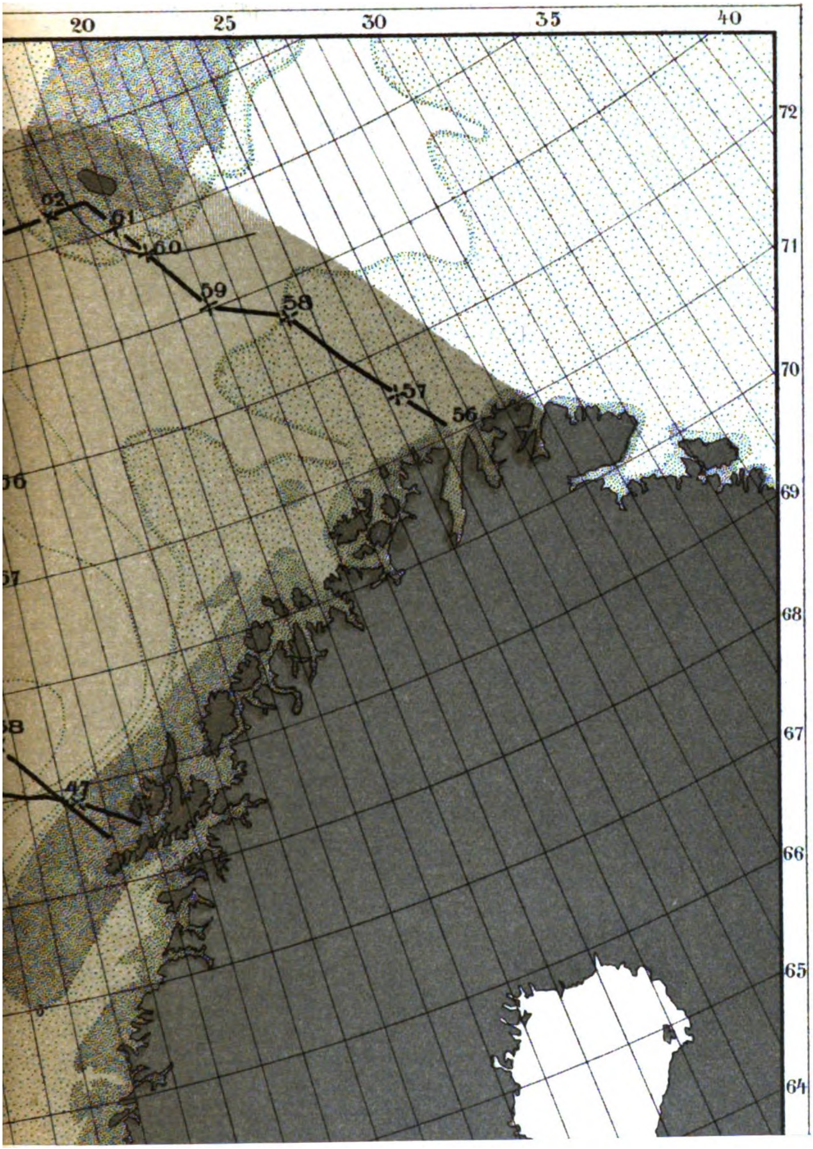
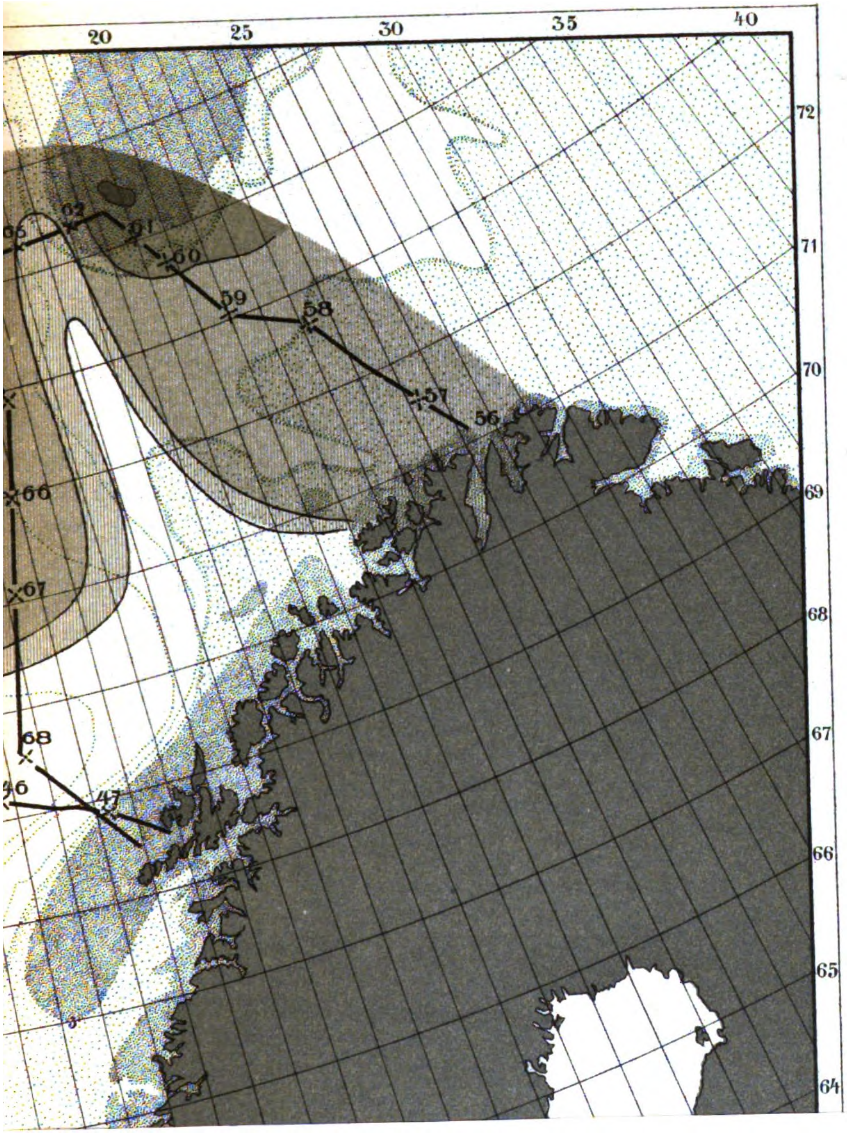
Pl. IV.



Pl.V.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Pl.VI.

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THE "MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910.

③

Species of PERIDINIUM indexed where underscored. B.

By JOHAN HJORT.

(From 'The Geographical Journal' for April and May, 1911.)

THE "MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910.*

By JOHAN HJORT.

(*From 'The Geographical Journal' for April and May*, 1911.)

In August, 1909, Sir John Murray wrote to me offering to defray the expenses of an expedition to the North Atlantic with the Norwegian research steamer, *Michael Sars*. Since the year 1900, I and my assistants had undertaken cruises with this vessel in the Norwegian sea. We had endeavoured to investigate the distribution of the ocean currents, as well as their movements and fluctuations, and we had also made a number of observations regarding the life-history of fishes and other organisms. We had often had reason to notice the influence which the Atlantic ocean exerts upon more northerly waters. We had seen how the varying volume of Atlantic water streaming over into the Norwegian sea and North sea may affect and qualify hydrographical conditions in those seas; and we had succeeded in establishing the fact that there is a great annual immigration of Atlantic organisms into North European coastal waters.

Only once had I had the opportunity previously of paying a short visit to the Atlantic ocean, on which occasion we succeeded in taking with the trawl, in a single haul at 500 fathoms, a number of fishes that included no fewer than 100 individuals belonging to new species. Since then I had often wished to explore the waters of the Atlantic, so that Sir John Murray's liberal offer came to me as a welcome surprise.

The Norwegian Government showed itself very indulgent towards our enterprise, and placed the vessel entirely at our disposition; and my colleagues, who have so long taken part in these researches, Professor H. H. Gran, Dr. Helland-Hansen, Mr. E. Koefoed, and Captain Thor Iversen, all signified their utmost willingness to join the expedition.

On completing our preparations we started off from Plymouth in the beginning of April, 1910, after being joined by Sir John Murray at that port. We first experimented with the trawl, and undertook hydrographical investigations to the west of Ireland, over the slope of the coast banks. Our course was then set across the Bay of Biscay, where we made a number of investigations, towards the north-west corner of Spain. From there we followed the Spanish and Portuguese coasts down to Gibraltar. Here we obtained a series of current measurements in the strait. Cadiz Bay was next examined; and careful hydrographical observations of the state of the currents were made over several sections of these interesting waters, while a series of trawlings were at the same time undertaken from the coast down to profound depths.

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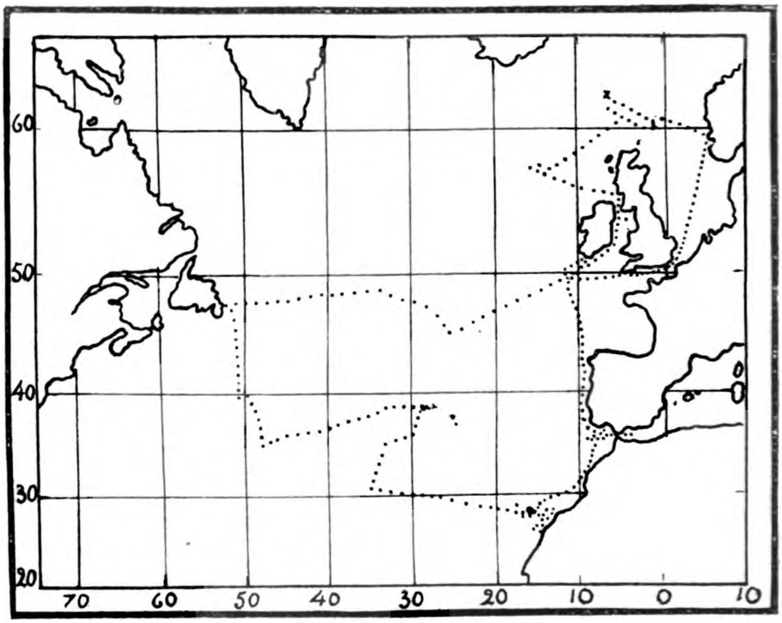
* Royal Geographical Society, January 16, 1911.

We then steamed in the direction of the Canary islands, and examined



Track of the "Michael Sars"

the African banks from the coast to the ocean floor; and subsequently commenced a large section of the Atlantic, visiting the Azores, the Sargasso sea, and eventually Newfoundland. Throughout the whole of this section, comprising 40 stations, we made constant hydrographical investigations and employed many different kinds of instruments for collecting plankton organisms of all sizes. A similar section was undertaken in July from Newfoundland over to Ireland (22 stations), and we concluded our researches by a more searching examination of the waters between Glasgow, Rockall, the Faroes and Shetland—that is to say, the sea to the south and north of the Wyville Thomson ridge—to study the transition from the Atlantic to the Norwegian sea.

During the four months that the cruise lasted a great deal was accomplished. For oceanographic science it cannot but be interesting to learn that a little steamer, of only 226 tons, could carry out so many and such multifarious researches right across one of the mighty oceans; and I will accordingly give a few figures to illustrate what was done.

In the case of *hydrographical* material we collected 2400 water-samples, more than 900 of which were from below the surface. At 110 stations we took 937 temperature-observations from below the surface, while as many as 1625 observations of the surface temperature were recorded during the cruise. In addition, we obtained 258 measurements of currents and seven measurements of the penetration of light beneath the surface. For the study of *vegetable plankton* we made 140 vertical hauls, and took 38 water-samples for filtering and 58 samples for examining with the centrifuge. For the *larger plankton* there were 95 vertical hauls with nets of different sizes, 193 horizontal hauls with silk nets, 80 horizontal hauls with pelagic trawls, and 18 hauls with a very large tow-net. *Trawlings* were undertaken on twenty-four occasions at different depths.

Our being able to carry out so many investigations, in spite of the fact that the ship traversed a distance of about 11,000 miles during the four months the cruise lasted, shows that oceanographic expeditions can be undertaken in small craft, and for a relatively moderate expenditure. And this will most likely be a matter for consideration when future expeditions are planned.

We returned from our cruise on August 15. In the five months that have since elapsed we have studied as much as we were able of the large amount of material collected. Dr. Helland-Hansen has taken charge of the hydrographical material and Professor Gran of the Phytoplankton, while I have myself organized the treatment of the zoological material. But it is quite evident that we have not yet succeeded in examining more than a mere fraction of the whole.

So, then, while anxious to comply with the request of the Royal Geographical Society, and to describe the results of our expedition, I feel that I am unable to do more to-day than to give a *few instances* of the experiences yielded by our mode of working, and to explain the ideas which have inspired our labours. My aim will be especially to point out those problems for future solution that have arisen during the course of our work. How rich a field for future research there is in the North Atlantic was what chiefly impressed both myself and my colleagues, and it is my hope that the contributions to our knowledge of that ocean which I am now, with their assistance, in a position to put before you, will help to stimulate interest in future researches there.

HYDROGRAPHICAL INVESTIGATIONS.

At 110 stations we collected material for determining *the temperature and salinity of the sea-water*. The temperature observations have now been corrected, the water-samples have been titrated, and the results are set down in vertical sections and charts showing the distribution of temperature and salinity at the different depths. I shall now give you a few instances of these results.*

Fig. 1 shows the vertical distribution of temperature and salinity in the sea between Newfoundland and Ireland in the month of July, 1910. Throughout nearly the whole section there is a layer with salinities of 35·5 per thousand in the uppermost 150–200 metres. Both salinities and temperatures decrease in fairly regular proportion as we descend, until we reach a uniform layer termed "bottom water," in which the temperature is slightly under 2·5° C., and the salinity is about 34·9 per thousand. It is noteworthy that this salinity is exactly the same as has been found in the bottom water of the Norwegian sea during the previous investigations. During the cruise of the *Michael Sars* in the Atlantic, this same salinity has been discovered both between the Canary islands and the Azores, and between the Azores and Newfoundland, and also outside the Bay of Biscay.

This uniform bottom water lies deeper in the eastern portion of the North Atlantic, off the south coast of Europe and the north coast of Africa, than in the western or north-western portion of the coast of America. East of Newfoundland it attains a comparatively high level, as will appear from the chart in Fig. 2, which shows the conditions at a depth of 500 fathoms. This would seem to indicate that the bottom water of the North Atlantic comes from the north-western portion of that ocean.

The chart shows clearly the influence of the Mediterranean, which has at first been studied by Dr. J. Y. Buchanan, and lately by Dr. N. J. Nielsen of the Danish Ocean Research. Very salt and comparatively warm water streams out of the Mediterranean and sinks through the deeper layers; outside Spain it mainly flows northwards, owing to the effect of the Earth's rotation; another portion seems to follow the ordinary stream towards the west and south-west. Between the comparatively fresh cold water in the north-west and the relatively warm salt water outside Spain a belt extends from west of the Azores as far as the Faroes and Iceland—with fairly uniform salinities of 35–35·5 per thousand, and temperatures of 6–8° C.

In Fig. 1 we see at stations 81 and 82 a comparatively large mass of the salt warm water. It is considerably thinner further east at station 85.

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* The temperatures have been mainly recorded by means of Richter's reversing thermometer. In 517 cases we used the same two thermometers side by side. The difference between the corrected values of these two thermometers was on an average about 0·01° C. Mr. Helland-Hansen is of opinion that the accuracy of the temperature-determinations can be set at a few hundredths of a degree. The water-samples were for the most part collected with Ekman's reversing water-bottle. Salinities were determined by chlorine titrations. All the samples were titrated twice, and the salinities are considered to be correct to about 0·01 per thousand. The observations were mostly taken at the surface and at the following depths: 25, 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, 600, 800, and 1000 fathoms. There are comparatively few observations from greater depths.

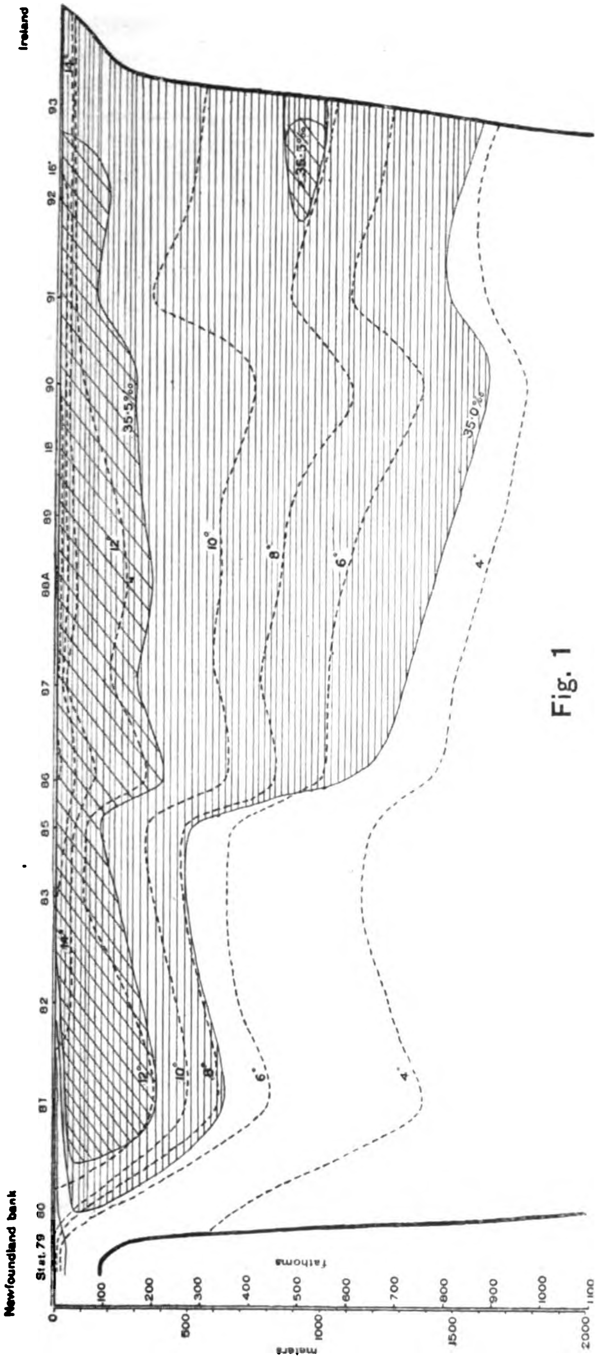

Fig. 1

VERTICAL DISTRIBUTION OF TEMPERATURE AND SALINITY BETWEEN NEWFOUNDLAND AND IRELAND, JULY, 1910.

Fig. 3 depicts a section from the Sargasso sea to Newfoundland. It shows a division which is even more marked. The conditions at station 66 are exceedingly remarkable. The very salt warm water from the Sargasso sea and its neighbourhood was completely separated by a sort of cold wedge from a similar warm salt-water layer nearer America. The chart in Fig. 4 shows the position of affairs at a depth of 200 fathoms. It is, however, very doubtful whether there is really such a big sunderance in

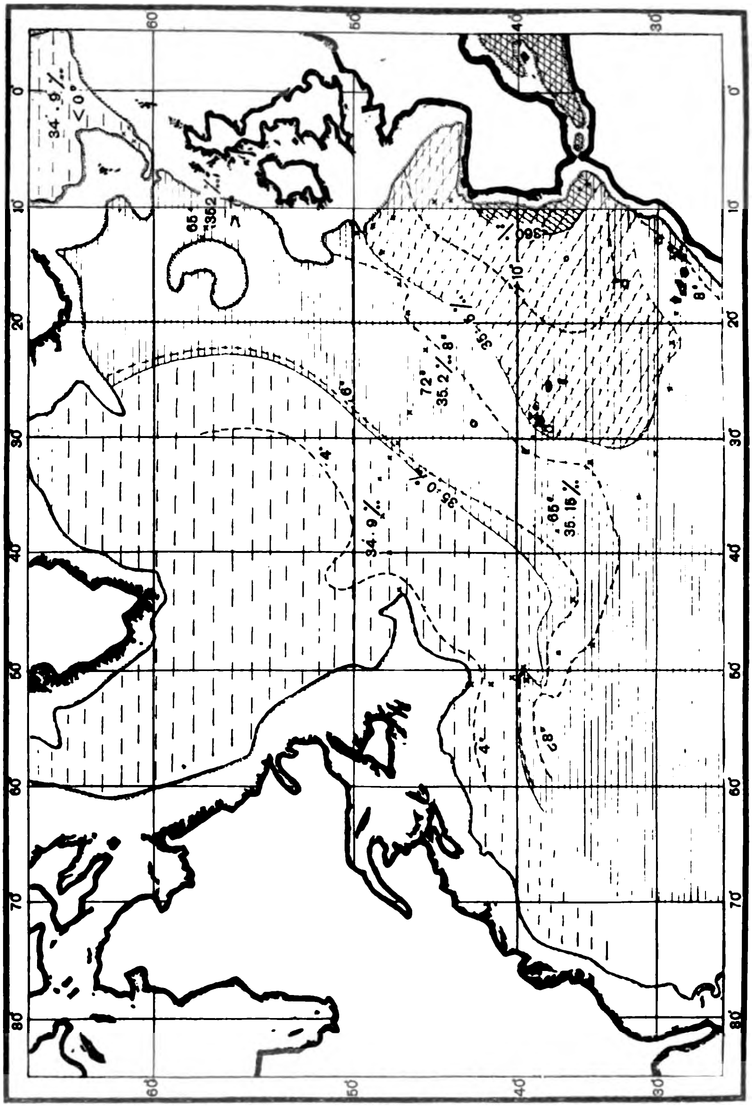

Fig. 2

CONDITIONS AT 500 ENGL. FATHOMS.

the stream as the curves would appear to indicate. Only further and more thorough investigations can settle this question, which is important for properly understanding the whole system of currents in these waters. If the chart is correct there must have been also a counter stream flowing towards the south-west, which sundered the water masses moving towards the north-east. A larger number of observations would perhaps have shown that the curves should be drawn otherwise, or this may only have been the state of affairs at the time the investigations were made.

If we compare our temperatures with those of the *Challenger*, we find that *they agree most satisfactorily, as far as the deep layers are concerned*, and the temperature observations of the *Challenger* seem to have been very good. In Fig. 5 we have a comparison between the distribution of temperature at the *Challenger* station 354, in May, 1876, and the *Michael Sars*' station 51, in June, 1910. There are some small points of disagreement, but the average curves (dotted) of the *Challenger* coincide pretty well with those of the *Michael Sars*. Fig. 6 shows a similar comparison between the *Challenger's* station 65, in June, 1873, and the *Michael Sars*' station 65, in June, 1910. Here the differences are astonishingly great, even exceeding 3° C. at the same depth in the mid water-layers. This cannot be ascribed to an error of method. In the first place the temperatures at the greatest depth accord satisfactorily in the two sets of investigations,

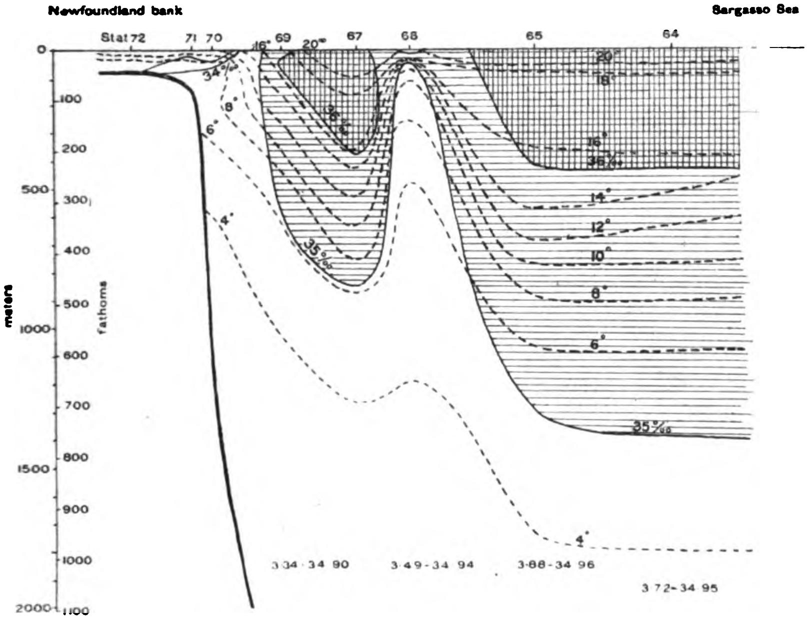

Fig. 3

SARGASSO SEA TO NEWFOUNDLAND.

and further the stations are located in an area where there are not known to be any rapid changes.

If we look at all the stations from the cruise of the *Challenger* in the summer of 1873, which are situated in the neighbourhood of the *Michael Sars'* stations of a summer thirty-seven years later, we will find everywhere that the water in the mid layers was much warmer in 1873 than in 1910.

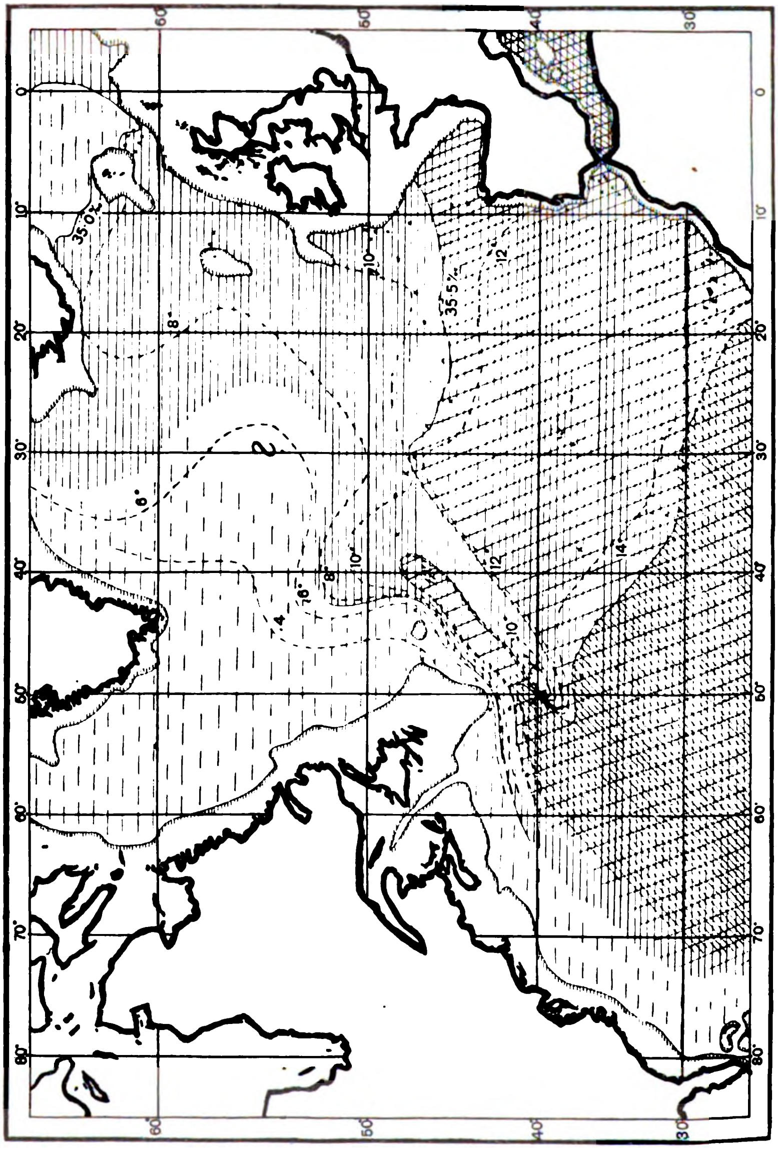

Fig. 4

CONDITIONS AT 200 ENGL. FATHOMS.

The table on p. 358 shows the difference in temperature (in ° C.) between one of the *Challenger's* and one of the *Michael Sars'* stations. The differences go up to about 5° in the mid water-layers, but sink to 0°·1 and 0°·4 respectively in deep water. This seems to indicate that there are such very great fluctuations from year to year in the degree of warmth in these mid layers that they even exceed the fluctuations in the seasons.

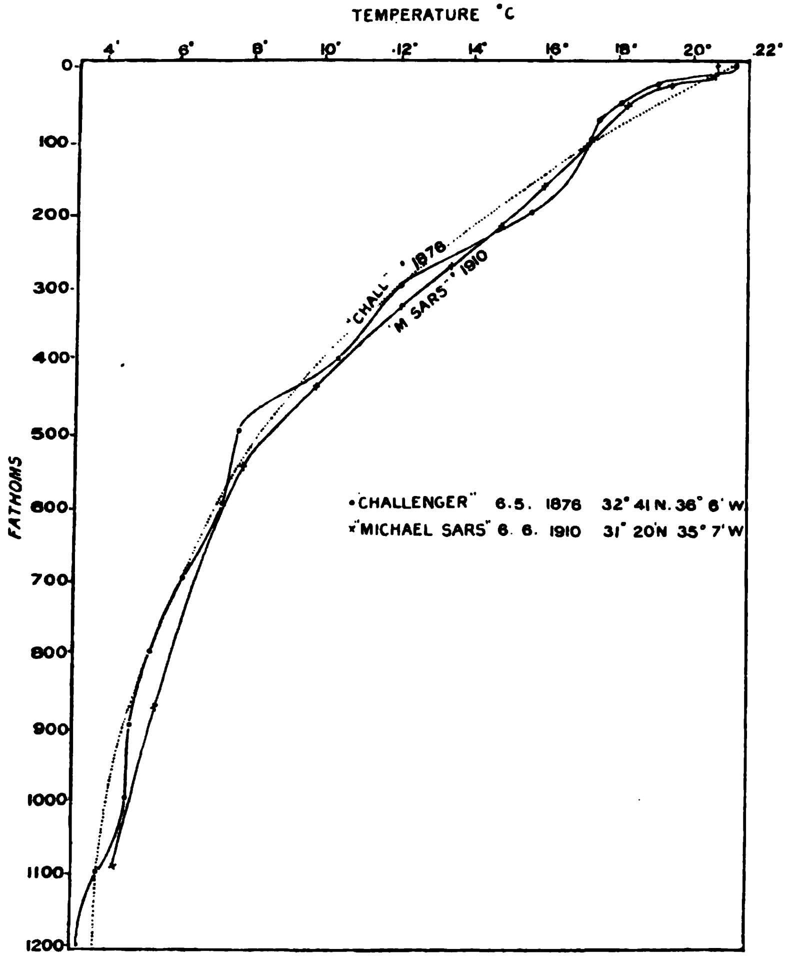

Fig. 5

TEMPERATURE OF *CHALLENGER* AND *MICHAEL SARS'* EXPEDITIONS.

It is obvious that fluctuations of this kind in the degree of warmth of the Atlantic ocean are most important and need further investigation. In the Norwegian sea such fluctuations in water flowing in from the Atlantic have been already previously investigated by the *Michael Sars.*

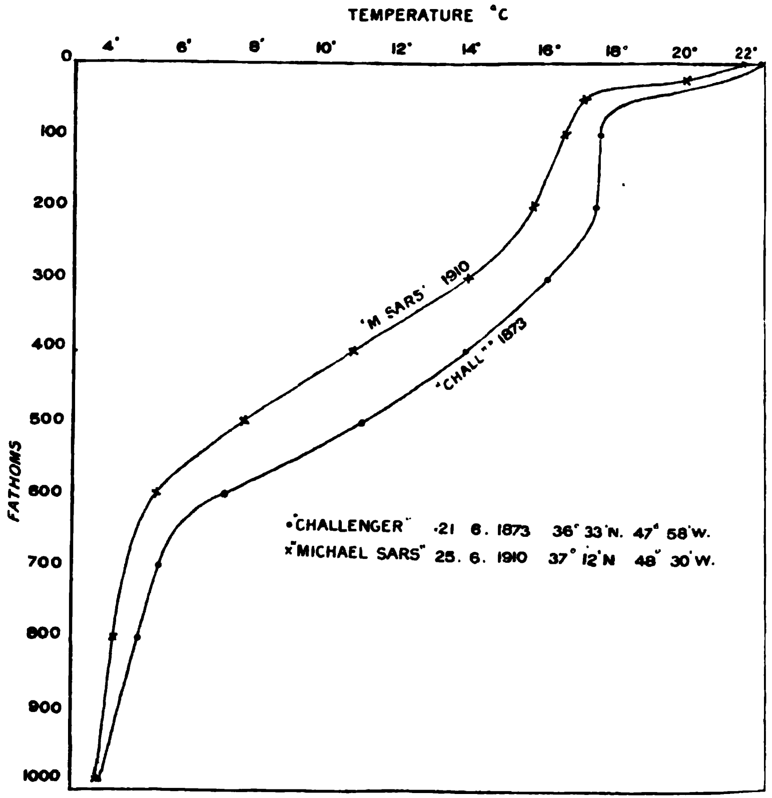

Fig. 6

Temperature of the Atlantic.

June, 1873 (*Challenger*), and June, 1910 (*Michael Sars*).

Difference of Temperature (° C.)

Depth, Fathoms.	A Between *Challenger*, stat. 65. and *Michael Sars*, „ 65.	B *Ch.* stat. 66. *M.S.* „ 63.	C *Ch.* stat. 69. *M.S.* „ 60.
0	0°·6	+ 1°·2	2°·3
100	1°·1	0°·5	0°·8
200	1°·7	1°·2	1°·6
300	2°·2	3°·7	2°·8
400	3°·2	4°·8	2°·8
500	3°·2	4°·3	2°·0
600	1°·9	1°·9	0°·7
800	0°·7	—	—
1000	0°·1	—	0°·4
	Ch. 65, 36° 33′ N., 47° 58′ W. *M.S.* 65, 37° 12′ N., 48° 30′ W.	*Ch.* 66, 37° 24′ N., 44° 14′ W. *M.S.* 63, 36° 5′ N., 43° 58′ W.	*Ch.* 69, 38° 23 N., 37° 31′ W. *M.S.* 60, 41° 39′ N., 51° 4′ W.

These determinations of the temperatures and salinities of salt water will subsequently be utilized for dynamic calculations. It will thus be possible to draw conclusions as to the *movements* of the different water-layers. These movements the expedition endeavoured also to investigate by means of direct *current measurements* with the propeller current-meter which *Ekman* has constructed.

In the Strait of Gibraltar we tried first to anchor one of the lifeboats fore and aft, as had often been done previously in Norwegian waters. However, the strong current broke the lines repeatedly. We accordingly anchored the ship itself, with 1½-inch steel wire and a warp anchor, in about 200 fathoms. The ship lay thus on April 30, from 2.30 a.m. till 5 p.m. During this time we took seventy measurements at eight different depths.

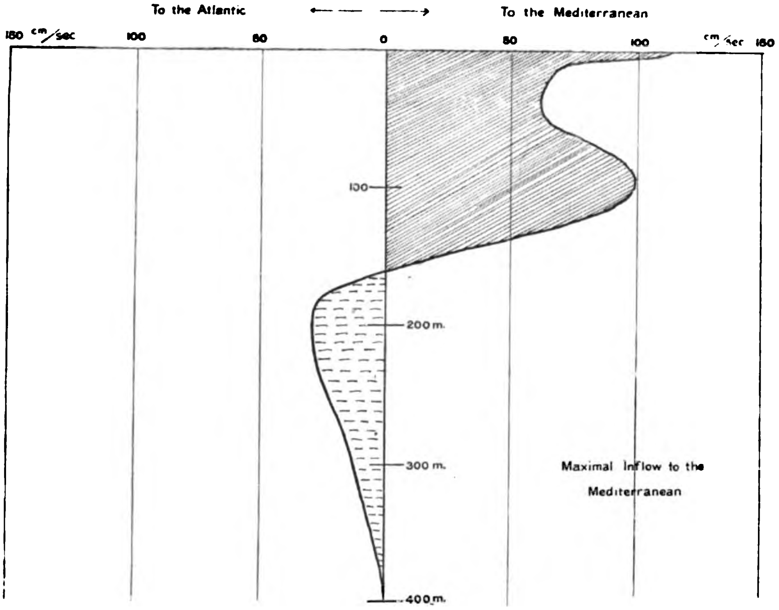

Fig. 7

MOVEMENTS AT DIFFERENT DEPTHS IN THE STRAIT OF GIBRALTAR.

Figs. 7 and 8 show the results of these measurements, calculated for the direction along the axis of the Strait.* The water-layers flowing into the Mediterranean are indicated by oblique lines, and the layers going out into the Atlantic by broken lines. Fig. 7 gives the conditions at 9 a.m., when the inflow into the Mediterranean was at its height. Fig. 8 gives the average of the measurements at 2 o'clock in the morning and 3 o'clock in the afternoon. A comparison of the two figures shows that the effects of the tidal water are very great throughout the whole mass of water from the surface to the bottom. The horizontal scale give the velocities in centimetres per second. During the inflow (Fig. 7) the velocity in the upper instreaming layer was about 1 metre per second, while in the lower west-flowing layer it did not exceed $\frac{1}{3}$ metre. During the *outflow* from the Mediterranean to the Atlantic (Fig. 8) there

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* In working up these results Dr. Helland-Hansen has been assisted by Dr. Hanzlik, of Prague.

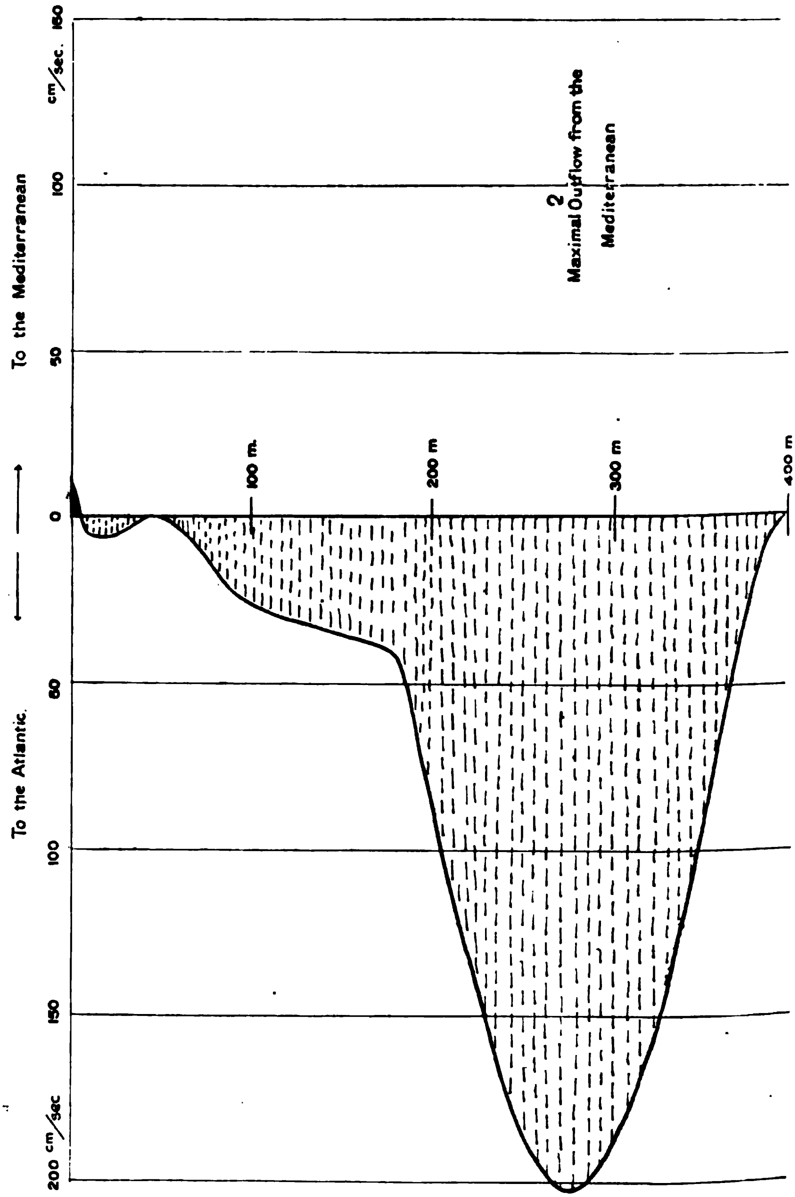

Fig. 8

MOVEMENTS AT DIFFERENT DEPTHS IN THE STRAIT OF GIBRALTAR.

was hardly any surface current, whereas the outward current at greater depths (300 metres) had a velocity as much as 2 metres per second. The real velocities were actually greater, as the current generally ran in a slightly oblique direction to the axis of the strait.

During our experiments with the large otter trawl on the bank south of the Azores on June 12, our trawl stuck fast on the bottom. Instead of immediately getting it clear, this otherwise unfortunate circumstance was made use of for taking current-measurements. The ship was thus anchored to the trawl at a depth of 524 fathoms (958 metres). In all we took ninety measurements at various depths down to 800 metres.

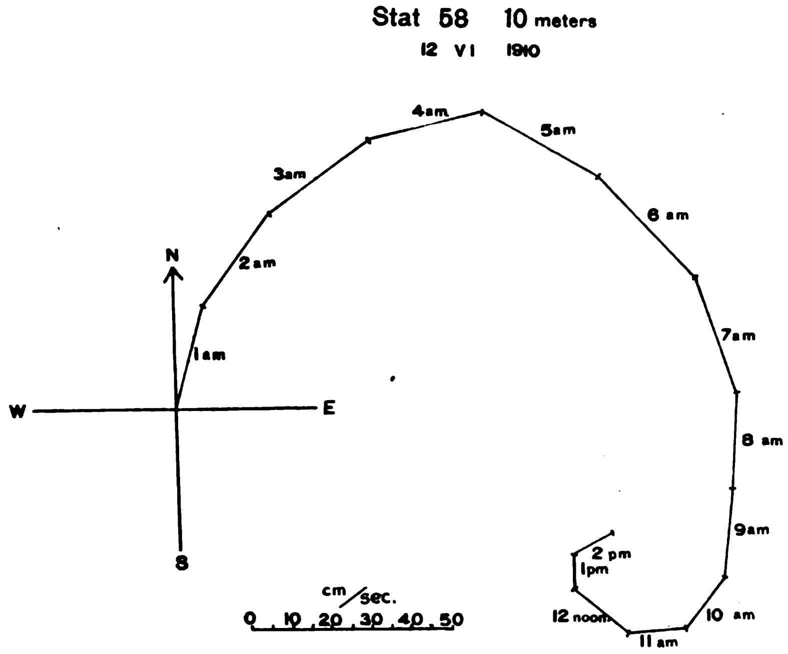

Fig. 9

CURRENT FROM HOUR TO HOUR AT DEPTH OF 10 METRES.

Fig. 9 shows the current from hour to hour at a depth of 10 metres. *The tidal movements can be distinctly seen.* The actual main current ran southwards with a velocity of 8–9 cm. per second.

In Fig. 10 we see the currents in the different layers at three intervals of time—I. at 3.30 a.m.; II. at 7 a.m.; III. at 10.45 a.m. On comparing the three figures we find that at all depths down as far as 800 metres there were tidal movements; the arrows all point to the right from I. through II. to III. On the whole the currents in the deeper layers flowed in a contrary direction to the movements in the upper ones. There was a strong current at 800 metres at 3.30 a.m.; but otherwise we found as a rule that the current was strongest close to the surface, while at 100 metres the velocity decreased and increased again at 200 metres.

The measurements show accordingly that there may be very considerable tidal currents even down as deep as 800 metres. The reason why they were so strong south of the Azores is probably to a great extent because the bottom there forms a large shoal, which the water presses up against.

Similar investigations with modern methods have never been undertaken before either in deep water or in the Strait of Gibraltar.

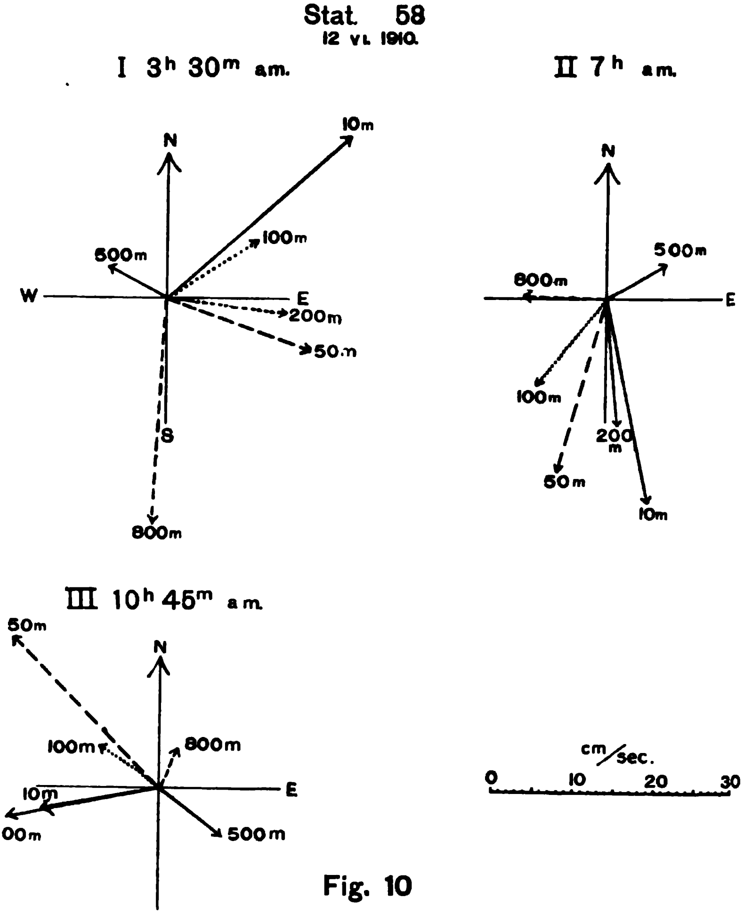

Fig. 10

CURRENTS IN DIFFERENT LAYERS.

That there are tidal movements in the open sea and such strong currents, even at depths over 400 fathoms (800 metres), is interesting for many reasons, as it assists us in understanding the ocean currents, the tide-wave, the distribution of living organisms, and of the deposits along the bottom of the sea.

It has long been a puzzle to find that at great depths in the sea there are stones which are not covered by deposits, though they must undoubtedly have lain at the bottom for a long period of time. On the slopes of the coast banks south-west of Ireland, we shot our trawl in about 1000 fathoms (1797 metres), and found, *inter alia*, numbers of stones.

Sir John Murray has given them to Dr. Peach for examination. As mentioned in Sir John Murray's lecture to the Royal Scottish Geographical Society in Edinburgh, on November 11, 1910, Dr. Peach "reports, that fully 20 per cent. are glaciated fragments. They consist of granite, gneiss, shales, sandstones, chalks, limestones, and flints, and some of these contain fossil remains. The condition of these fragments shows that in many instances they projected above the surface of the deposit in which they were embedded. Dr. Peach has no doubt that these stones were carried by ice during the later phases of the glacial period to the position in which they were found. They almost all belong to the series of sedimentary, metamorphosed, and erupted rocks now found *in situ* in this country and in Ireland. But the interesting question is: why have these fragments not been completely covered up by the shells which are continually falling from the surface? Telegraph engineers give reasons for believing that in some localities and depths the rate of accumulation is at least one inch in ten years; at this rate all rock fragments deposited during the glacial period should have been buried in the ooze far beyond the reach of the trawl. Most probably the tidal currents, which our observations showed to exist in deep water, extend right down to the bottom and remove the small Globigerina shells from any ridges. Still there may be other explanations of the facts." *

PHYTOPLANKTON.

Throughout the whole cruise of the *Challenger* the forms of plankton collected by the tow-nets were determined, as published in the Summary of Results, and a first attempt was made by Sir John Murray to estimate the quantity of calcium carbonate, in the form of shells and skeletons secreted by plankton organisms, to be found in a mass of ocean water 100 fathoms in depth by a square mile in area. The detailed examination of the Phytoplankton of the North Atlantic, with numerical determination of the individuals of different species, was first undertaken during Hensen's expedition in 1889, the results of which, by the way, have not yet been fully treated. Our knowledge has been further extended by the extensive researches of Cleve, and by valuable contributions from G. Murray, Whitting, and Blackman. The *Valdivia* expedition carried out the greater part of its investigations in the Antarctic and Indian oceans, *the researches in the Atlantic* being comparatively few. Our knowledge regarding the distribution of species in the Atlantic is, notwithstanding, still very incomplete.

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* *Scottish Geographical Magazine*, December, 1910.

The samples taken by tow-nets in the open sea could not any of them compare in quantity with what can be obtained in the coastal waters in the Norwegian sea. The only exceptions are the series taken to the west of Ireland and in the Bay of Biscay during April (stations 2, 3, 4, 7, 9, 10), where we met with large quantities of diatoms, even down to depths of over 100 metres.

The oceanic samples are, however, very rich in species, there being, as a rule, at least 50 species in every single sample from the upper layers down to a depth of 100 metres. Many of the species are so sparsely represented that it has only been possible to find a few individuals, but the majority of them have, in spite of their scanty numbers, a wide distribution throughout the warm seas, and they have also been found in the Indian ocean (*Valdivia*) and the Pacific (Kofoid). A few of them have not yet been described, though most of them are known from previous investigations. It will be a difficult matter to characterize the groups of species according to their geographical distribution within the area investigated; it can perhaps be done when our material has been fully treated, but certainly not as yet. All we can do at present is to distinguish the subtropical species from those which belong to temperate waters, and the oceanic species from the ones which have their centre of distribution along the coasts.

The various groups of plankton algæ adapt themselves in an entirely different manner to oceanic conditions of existence, and must, therefore, be treated separately.

1. *Cyanophyceæ*, or the bluish-green algæ, have comparatively very few pelagic representatives, but they include, on the other hand, several which are characteristic forms of the tropical seas. *Trichodesmium Thiebaulti* consists of threadlike strings of cells, united in more or less regularly formed yellowish-brown clusters, which in calm weather float up to the very surface, where they can be seen with the naked eye, and where they sometimes congregate in such dense masses as to constitute a distinct layer. The species does not occur outside ocean currents of subtropical origin, and Cleve hit on a characteristic definition of the tropical oceanic plankton in the Atlantic when he called it Desmoplankton. It was found at all stations from the Canary islands to the Newfoundland banks, and from there to the coast banks off Ireland.

Cyanophyceæ are not found pelagic in temperate or arctic marine areas, though a few species may occur in the summer in brackish water like the Baltic. In shallow fresh-water lakes, too, other species sometimes form the so-called *water-blossom* during the hottest part of the year.

2. *Diatoms* occur at times in larger *quantities* than any of the other plankton algæ, and they are to be found in all seas, from polar regions where the temperature is below 0° to the tropics, and along the coasts as well as in the open sea. Most of the species are restricted to the shallow coastal seas, and they form resting spores with thick cell walls

which sink to the bottom and ensure the survival of the species at unfavourable seasons of the year. However, there are also some species which are purely oceanic.

The diatoms, which are characteristic of the tropical and subtropical portions of the open Atlantic, are comparatively few, though some of them are quite characteristic: *Coscinodiscus rex*, the largest of all the pelagic diatoms, appears to the naked eye as a yellowish-brown bladder, over a millimetre in diameter; the cell-contents form quite a thin layer along the finely sculptured cell wall. *Planktoniella sol* and *Gossleriella tropica* are discoidal cells with a peculiar swimming apparatus radiating out from the edge; Planktoniella has a collar built up of delicate compartments, and Gossleriella a crown of fine silicious fibres.

The genera which predominate in temperate seas (Chætoceras, Rhizosolenia, Thalassiothrix) are in their way just as well equipped for a pelagic existence, and their swimming apparatus shows quite as many variations. But they need also just as much to increase their superficies and swimming powers, since in temperate seas they may be often swept into ocean currents with lower salinities and densities, where they often multiply prolifically. It should be mentioned that several of the oceanic diatoms, which are characteristic types of colder seas, are also to be found in smaller quantities even at the warmest stations, and this is especially the case with those species that occur in abundance in both the Arctic and Antarctic oceans (*Thalassiothrix longissima*, *Rhizosolenia hebetata f. semispina*); they cannot, therefore, be strictly regarded as examples of bipolar distribution.

The distinction between the coast plankton and oceanic plankton does not appear to be so easy to draw in the warm seas as it is in temperate waters. In our latitudes some of the coast plankton rest for several months during the darkest period of the year, while other species rest during the summer. Early in the spring the actual coast plankton is restricted to the shallow coast banks, but in the course of the summer and autumn a larger or smaller number of species is apt to follow the surface currents out to sea, where, however, they play quite a subordinate part compared with the oceanic species that are developed on the spot.

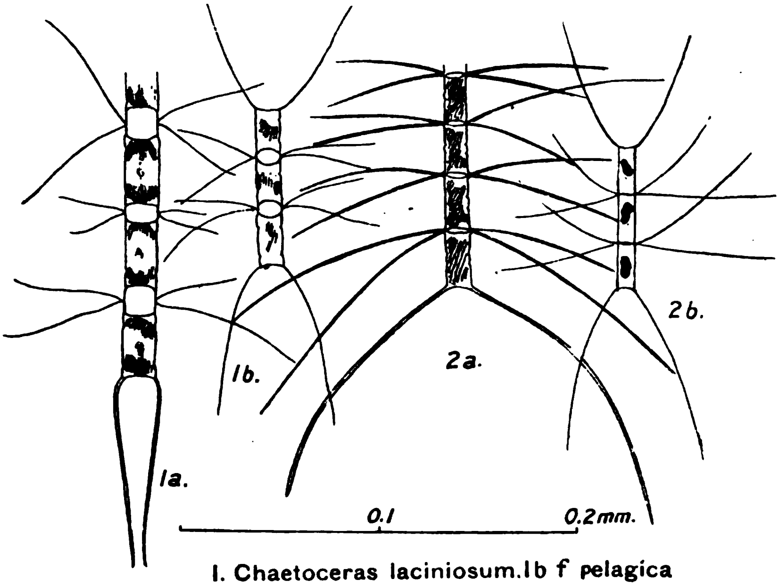
In warmer waters the diatoms of the coast plankton appear able to remain for a longer period outside their own particular areas than they do with us: very few of the plankton samples which we collected from the surface layers were entirely devoid of diatoms that properly belong to the coasts; they are found, as a rule, in small quantities, and are by no means so robust in their structure, having thinner cell walls and smaller dimensions than the corresponding forms near the coasts; they are, however, all the same undoubtedly capable of surviving. One characteristic instance of long wanderings to oceanic regions on the part of such degenerate coast forms we were able to account for in the course of our investigations. South of Iceland, from May to July and well on into the autumn, previous observers found a community of degenerate coast diatoms, especially

Chætoceras Schüttii and *Ch. laciniosum*, which occurs at times in large quantities in water of a salinity high enough to characterize it as unmixed Gulf Stream water (see Fig. 11). This community is totally distinct from the Iceland coast plankton, and it is quite out of the question to imagine that the algæ may have wandered out from the Iceland coast. Now, we found on our cruise exactly the same species in exactly the same degenerate forms in the Gulf Stream, out beyond the east coast of North America, so that they must undoubtedly have been carried off by the stream from the American coastal waters. As soon as the current carries them to the localities where conditions of existence are favourable for their development the diatoms increase in great abundance, but retain the weak structure and small dimensions which Professor Gran has understood as a sign of degeneration.

3. *Peridinea* form, along with diatoms, the bulk of the plankton that we obtain by means of tow-nets. By far the most of the species are purely oceanic, and the greater part of them belong to warm seas; and here, too, we find a much bigger variation in the organization of cells than we do in temperate ocean currents. As an instance may be mentioned the family of *Dinophysidæ*. In the northern temperate Atlantic ocean this family is represented by a few species of the genus Dinophysis (see Fig. 12). The commonest of these, *D. acuta,* consists of a linguiform compressed cell, furnished with two cilia. One of the cilia oscillates freely alongside a membrane on the one side, the other lies protected between two ring-shaped membranes near the anterior portion of the cell. The alga remains floating in the upper layers by means of the movements of its hair-like lash; its body is comparatively heavy.

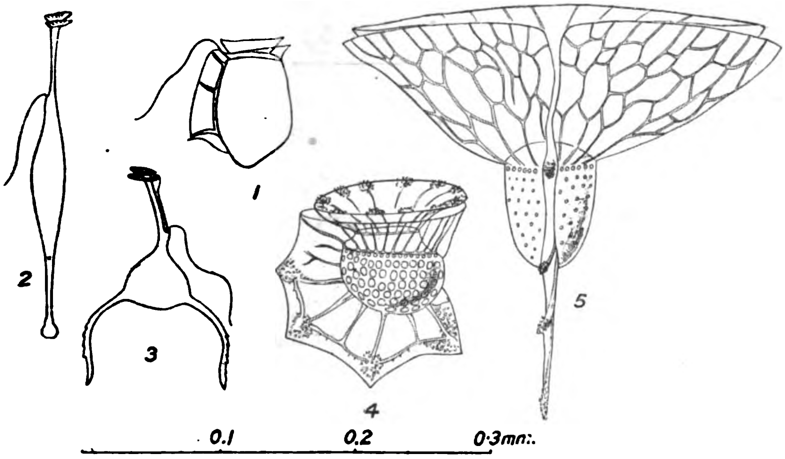
In warm seas we find an extraordinary variety of this type. In some genera the swimming apparatus is developed out of the different organs of the cell. The *Amphisolenia* have their whole cell drawn out into a hair-shaped formation, which carries the ring-shaped membranes on a little head at the anterior end. *Triposolenia* has the middle portion of its cell rounded, the head and membranes are placed on a long neck, and posteriorly the cell terminates in two curved thin legs which are not in the same plane.

Other genera have kept the cell-form almost as in Dinophysis, but the membranes are converted into swimming apparatus; in some cases the membrane at the side is the most highly developed, so that it also includes the posterior portion of the cell, and is stiffened with ramifying ribs (*Ornithocercus magnificus*); in others the ring-shaped membranes are changed into a complete parachute, which is also stiffened with ribs (*Ornithocercus splendidus*). A similar capacity for variation is likewise to be found in other families, chief among which may be mentioned Ceratium, the most important genus of them all; of which some species vary to a great extent, and can increase or reduce their superficies according to the density of their surrounding medium. The expedition has collected excellent



1. Chaetoceras laciniosum. 1b f pelagica
2 Ch. Schuettii 2b. f Oceanica

Fig. 11

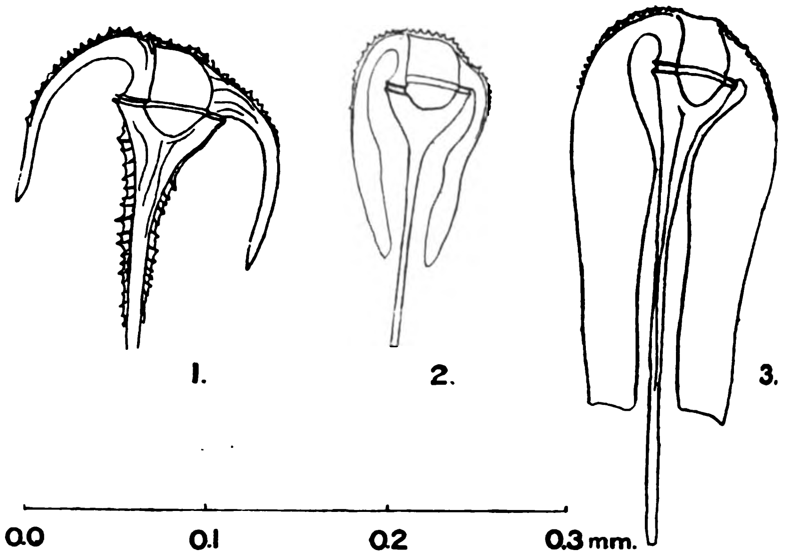


1. Dinophysis acuta. 2. Amphisolenia globifera. 3. Triposolenia bicornis.
4. Ornithocercus magnificus. 5. Ornithocercus splendidus.

Fig. 12

material for studying these variations; one species, *Ceratium platycorne* for instance, Fig. 13, is distinguished by the fact that its two posterior horns can be converted into flat wing-like swimming apparatus; towards the northern limit of its area of distribution it changes over, however, to a form with quite cylindrical horns, which caused it to be described formerly as a distinct species, *C. compressum*.

We are able to collect all these organisms with the ordinary tow-nets of miller-silk, the meshes of which are 0·04–0·06 mm. in diameter. In coastal waters they sometimes occur in large quantities, but in the open Atlantic they are only found in scanty numbers, as a rule not more than ten individuals per litre of all the species put together; and this, too, even in the layers nearest the surface, which afford the most favourable conditions for existence.



Ceratium platycorne.

1. F. compressa. 2 3 F. normalis.

Fig. 13

The greater portion of the plant substances in these oceanic waters consists of organisms, 0·02 mm. and less in diameter, which generally pass through the meshes of even the finest tow-nets; and the most valuable botanical result of our expedition has been that we have shown the possibility of examining these organisms throughout the whole cruise in their living state, and of determining the quantities of the different species occurring in each litre of sea-water at different depths.

As early as the *Challenger* expedition, Sir John Murray drew attention to their importance, as he found that the stomach-contents of salpæ mainly consisted of these small organisms, and he could also demonstrate their existence in sea-water on several occasions.

Later on Hensen made improvements in the tow-nets, assuming apparently that he could by means of them secure specimens of everything living that floats in the sea. When, accordingly, after his great expedition in 1889, he was unable to show any substantial quantities of smaller organisms, people began to doubt their existence, or at any rate their significance. George Murray pointed out anew that the principal family, the calcareous flagellates, is universally distributed throughout the seas; and Lohmann, whose plankton investigations have done much to improve both our knowledge and methods, made systematic researches with filters of fine construction, to ascertain their occurrence, especially in the Mediterranean and Baltic. He also introduced for the study of the smallest organisms a little hand centrifuge, which has done excellent service in waters rich in plankton.

During the *Michael Sars* expedition we employed, in addition to this, a large centrifuge driven by steam-power, which enabled us to centrifuge more than a litre of water at a time. The water-samples were taken up with water-bottles from different depths, and as a rule 300 cm. of each sample were subjected to the centrifugal machine. The water at the bottom of the centrifuge glasses, which contained the plankton algæ, was concentrated by means of a little hand centrifuge; so that it was possible to place the whole contents in a single drop of water below the microscope.

In this way we were able to study the quantitative occurrence of the different species at different depths during the whole expedition. We succeeded in discovering a whole series of quite unknown forms (see Fig. 14), especially in the case of the calcareous flagellates; and our investigations also enabled us to get a much clearer idea about the distribution of plants in relation to depth.

To sum up, our chief results are as follows:—

1. The quantity of plankton in the open Atlantic is far less than what is found in coastal seas.

2. At most of the stations where investigations took place the maximum of plant-substance was found at a depth of about 50 metres; it was, as a rule, scanty in the immediate neighbourhood of the surface, but appeared to be almost as abundant at 10 metres as at 50 metres. There was thus about the same quantity of plants all the way down from 10 metres to 50 metres.

At 75 metres the quantity was, as a rule, not more than half what we met with at 50 metres, and at 100 metres there was only about a tenth part.

This was the case with oceanic water. Where there was an admixture of coastal water, and an evident distinction between the surface layer and the deeper layers, the surface layer was comparatively richer in plants.

3. The different species are distributed, each in its own characteristic fashion, in regard to depth. The peridinea keep comparatively near the surface, the diatoms prefer the deepest layers, while the coccolithophoridæ occupy an intermediate position.

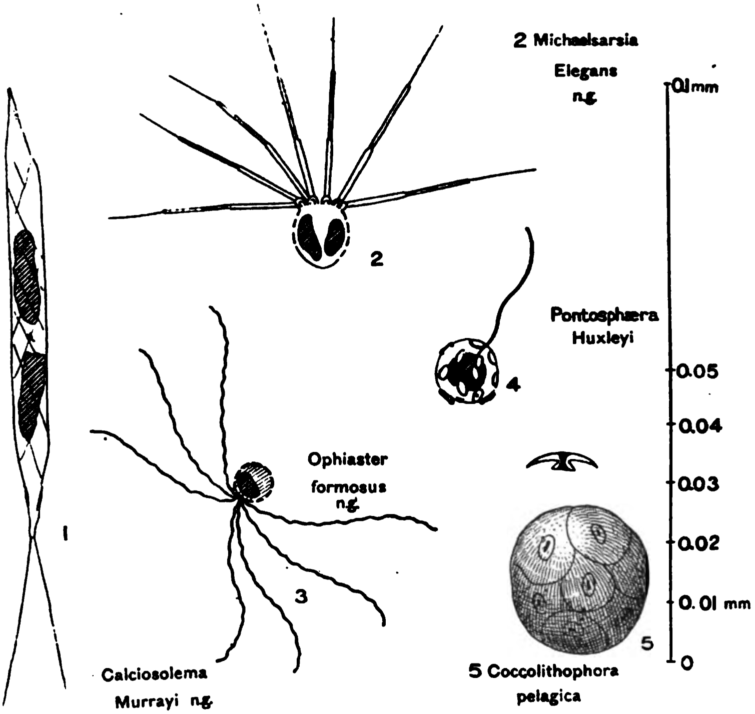

2 Michaelsarsia Elegans n.g.
0.1mm
2
Pontosphæra Huxleyi
4
0.05
0.04
Ophiaster formosus n.g.
0.03
0.02
1
3
0. 01 mm
5
0
Calciosolema Murrayi n.g.
5 Coccolithophora pelagica

Fig. 14

4. The number of living plant cells in the open Atlantic throughout the most densely populated water-layers (10–50 metres) varies, as a rule, between 3000 and 12,000 cells per litre of sea-water. Of these, about half are coccolithophoridæ, the rest being peridinea cells with a few naked flagellates and a sprinkling of diatoms.

THE LARGER ORGANISMS.*

Deep-sea Fishes and Crustaceans.

Since the *Challenger* expedition laid the first foundation of our knowledge regarding the animal world of the deep sea, many succeeding expeditions have bountifully added to our store. As an instance, I may mention that we now know one thousand different species of deep-sea

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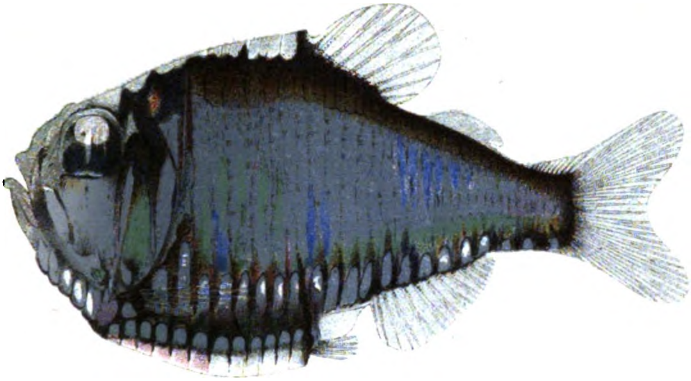
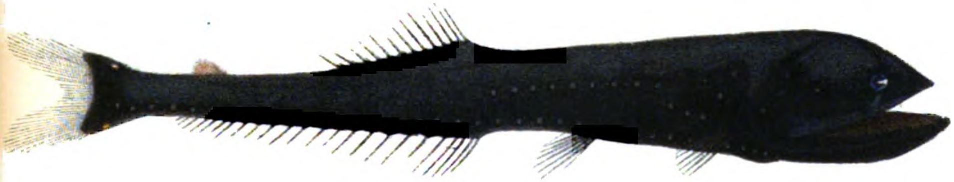
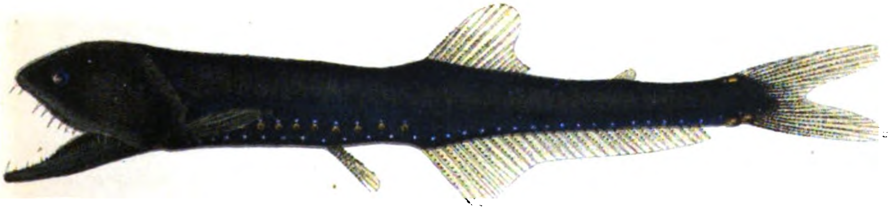
* In working up this material I have had the assistance of Mr. Einar Koefoed, Mr. Einar Lea, and Mr. Oscar Sund.



ARGYROPELECUS AFFINIS. GARM.



GONOSTOMA GRANDE. COLLETT.



GONOSTOMA ELONGATUM. GTHR.

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fishes, and that the German *Valdivia* expedition alone discovered no fewer than sixty-three new species.

Regarding these many species, however, only very little is known. In the case of quite a number of them we are acquainted merely with one, or, at most, a few specimens, while we are in almost complete ignorance as to their biology, their propagation, development-history, growth, and outward conditions of life.

The view which generally prevails in literature nowadays is, that the sea contains a motley abundance of forms either along its bottom or floating within its waters, subject to a uniformity of outward conditions of existence —that is to say, passing their lives in absolute darkness—and in a medium with constant temperature and other physical surroundings.

To biologists this view concerning the animal life of the deep sea has presented many difficulties. How is it that in a constant medium of the kind conceived there exist side by side so many distinct forms? And how, again, can animals with large eyes manage to live alongside blind forms? Why are some species furnished with numerous highly developed light-organs, while in the case of others these are entirely wanting? And how, too, comes it that within the same groups of animals, very often in closely related species, the colours vary so remarkably, although the outer medium is the same?

These questions have become all the more pressing now that biological ocean research has discovered instances where in the same area of the sea there occur many different animal forms, each possessed of its own peculiarities in mode of life, habitat, and other respects, so that each species has its own characteristic area of distribution, even though it may occasionally be found together with its neighbours in the same catch Our study of the spawning-grounds of the cod family (*Gadidæ*) in the North sea and Norwegian sea has shown us, for instance, that each of seventeen species has its particular spawning area, each species during the spawning period seeking out distinct characteristic depths, temperatures, and salinities; so that just as from a morphological point of view the species may be characterized by a definite form or structure, so, too, it is possible, to characterize it by certain well-defined conditions of existence. These conditions characterize a given species quite as much as any morphological description, and in fact, for a proper conception of the species, both methods of investigation are supplementary.

Now, if we wish to investigate the conditions of existence under which animals live, we must naturally first of all ascertain *where* they live, which, in the sea, will be tantamount to discovering *the depth* where they flourish. This alone can enlighten us regarding the conditions of light, of temperature, and of salinity which are requisite for their existence.

Our knowledge regarding the haunts of the smaller organisms has advanced greatly in recent years owing to the fact that we have made use of small closing nets. But, with regard to the larger animals, especially fishes, we still possess little knowledge, despite the great exertions made in this direction above all others by the Prince of Monaco and the *Valdivia* expedition.

Sir John Murray seems first of all to have had the idea that fishes may occur in intermediate layers. Thus, Gunther, in his treatise on the '*Challenger* Deep-Sea Fishes,' says—

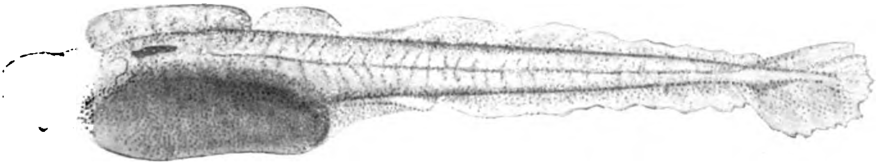
" I formerly assumed that the fishes of the open sea were living either near the surface or at the botton, but I think now that Mr. Murray is right in supposing that certain fishes live habitually in intermediate strata, without ever coming to the surface or descending to the bottom."

The *Valdivia* expedition made a special endeavour to ascertain the approximate limits of depth within which the various species of fish occurred. Brauer's excellent work on ' Fishes of the Deep Sea,' describes the efforts of the expedition in this direction. To a certain extent they made use of closing nets, but in these they only succeeded in capturing five out of the 151 species of pelagic fishes secured by the expedition. They also made the experiment of sinking bag-nets to different depths at the same station (graduated catches). In the Gulf of Guinea they took by this means (at station 66) in a haul with a large bag-net, from a depth of 3000 metres to the surface, thirty specimens of *Cyclothone livida*, whereas in a haul from 700 metres to the surface at the same place no specimens of this species were obtained; in this manner they elicited a great deal of valuable information regarding the depth at which the different species occur, though, as Brauer himself confesses, they did not succeed in defining the *upper and lower limits within which the deep-sea fishes live.*

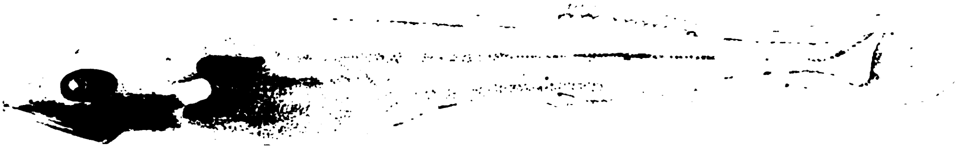
When fitting out the *Michael Sars* expedition, I kept ever in mind that one of the most important of all our aims should be to try and develop a method which would yield more information regarding the vertical distribution of deep-sea fishes.

My first idea was to devote the bulk of our work to very large closing nets, and we accordingly constructed two excellent closing nets 3 metres in diameter at the mouth, one being of silk and the other of fine shrimp-net, by means of which during the expedition we made some very successful hauls. On thinking matters over more carefully, however, I realized the many serious deficiencies of vertical closing nets. Their chief fault is that they catch far too little.

We may take it for granted that the larger fish, at any rate, are only caught by pure accident, as it is always single specimens that are secured. It is the smallest forms which occur in large quantities, and especially the genus Cyclothone, which alone can be investigated with instruments of this kind. But there is, besides, the disadvantage that it is very difficult to know *exactly* at what depth the net has closed, because it is necessary to calculate the time taken by the slip-lead to reach it, and it would be impossible to stop hauling in without risking the loss of all its contents. A further grave objection is the enormous length of time which these vertical hauls require when the depths are great, as it is necessary to wind in

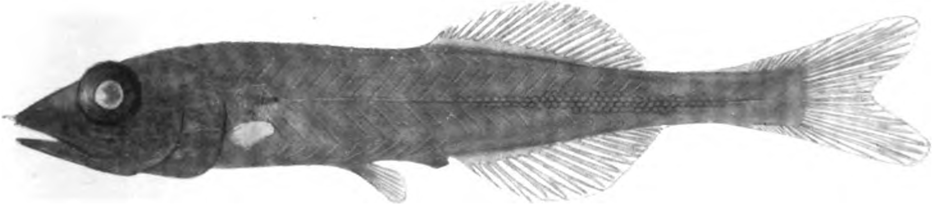


0.9 cm.



1.2 cm.

1.6 cm.



5.2 cm.

LARVA AND YOUNG OF ALEPOCEPHALUS.

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slowly. Our closing nets were, therefore, merely designed to serve as a check on other methods, and were employed solely for this purpose.

The ideal instrument for capturing the larger pelagic organisms would be a big tow-net or pelagic trawl, which could be sunk closed to the requisite depth, then opened and towed at a carefully ascertained depth, and finally closed again and hauled in. Such an instrument would be capable of capturing many of the larger animals, and it would secure them, too, at known depths. However, an instrument of this kind would naturally be extremely complicated, too much so, in fact, to prove reliable under our present system of working, and it would further entail a great expenditure of time. It would not be possible to operate many of these tow-nets simultaneously (amongst other reasons, because of the slip-leads), and, consequently, it would be necessary to undertake a series of hauls at the different depths.

This being the case, I gave up the idea of trying to construct any such instrument. A more practical plan seemed to be to try and tow a number of instruments simultaneously at different depths, and to compare the catches thus made with each other. I could thereby ensure all the hauls being made at the same time, and would be substituting horizontal for vertical "graduated catches." I hoped, further, by means of long-continued hauls, of, say, a whole night's or a whole day's duration, to reduce the error inherent in this method, namely, that the instruments would be apt to make captures during the process of lowering and hauling in. Provided that catches were large, it seemed to me that the mere numbers would demonstrate *sufficiently convincingly* at what depths the captures had been made.

Thanks to a practical arrangement, we succeeded in towing ten different instruments from two wire lines. It would undoubtedly have been better for purposes of comparison if they had all been alike, but in that case they would have had to be small. To be able to operate as many appliances as possible simultaneously, we had to have small ones (tow-nets) and large ones (Dr. C. G. Petersen's young-fish trawl) alternately, and my experience leads me to assume that they were all towed at a depth about equal to half the length of the wire out. The way they were set naturally depended to a great extend upon conditions on board the ship, but when we had got everything in order, we endeavoured, as far as possible, to make use of the same procedure at every station (see Fig. 15).

The arrangement generally adopted was as follows :—

At the surface	1 silk net of 1 metre diameter.
„ 50 metres	1 „ „ „ „
„ 100 „	1 „ „ „ „
„ 150 „	1 young-fish trawl.
„ 300 „	1 silk net of ¾ metre diameter.
„ 500 „	1 young-fish trawl.
„ 750 „	1 silk net of ¾ metre diameter.
„ 1000 „	1 young-fish trawl.
„ 1250 „	1 silk net of ¾ metre diameter.
„ 1500 „	1 large tow-net of 3 metres diameter (made of shrimp-net) or a young-fish trawl.

With this, or a corresponding arrangement, we carried out some long hauls at about thirty stations, off the Canary islands, in the Sargasso sea, between the Azores and Newfoundland, and from Newfoundland to Ireland. Some hauls were made in the daytime and others at night.

In this manner we collected a very large amount of material consisting of many kinds of pelagic organisms—fishes, cephalopods, crustaceans, medusæ, etc. I will here merely mention a few instances of the evidences our material affords as to the occurrence of these animals at different depths. To illustrate the method employed, I will begin with the remarkable and well-known *Sternoptychid: Argyropelecus hemigymnus.* Of this species we caught 287 individuals at the different stations, widely distributed over the Northern Atlantic. Now, if we arrange the 287 individuals according to depth, we get the following table :—

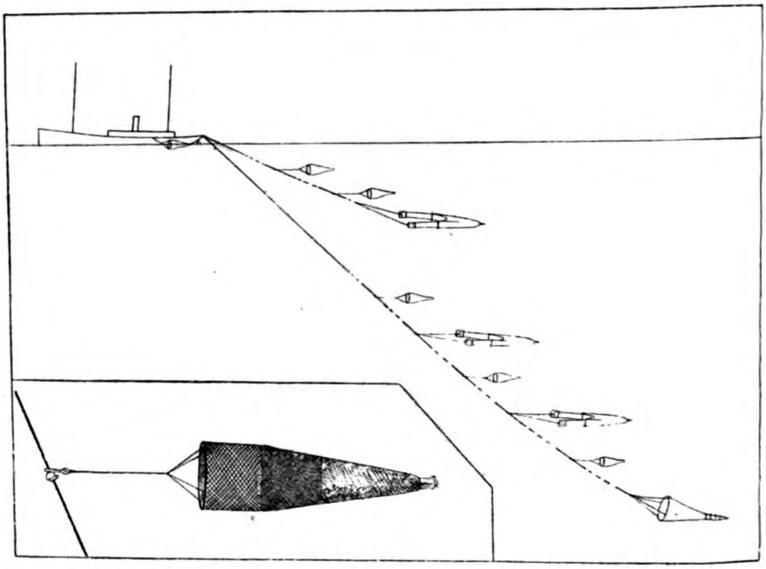
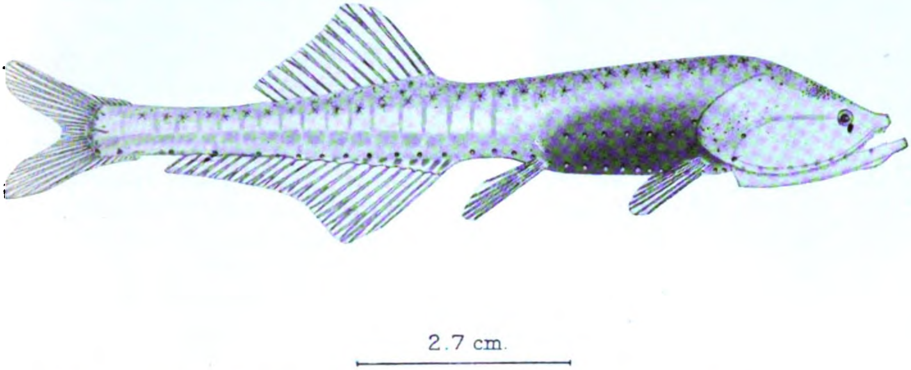


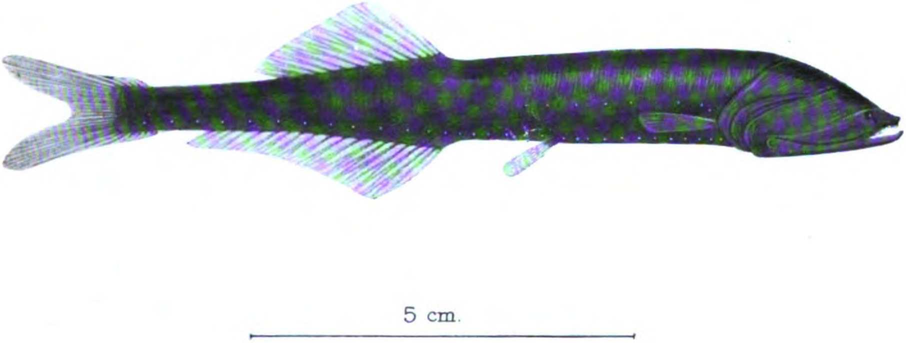
Fig. 15

TOW-NETS AT DIFFERENT DEPTHS.

At the surface	0
„ 50 metres	0
„ 100 „	0
„ 150 „	62
„ 300 „	156
„ 500 „	48
„ 750 „	0
„ 1000 „	6
„ 1250 „	0
„ 1500 „	11
„ 2000 „	4



CYCLOTHONE SIGNATA. 1000 mtr. Wire.



CYCLOTHONE MICRODON. 3000 mtr. Wire.

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The bulk occurred at depths between 150 and 500 metres, no individuals were caught above 150 metres, and only about 7 per cent. were taken at depths lower than 500 metres. If we assume, then, that these 7 per cent. were captured during the process of hauling in the appliances, and that none of them live at depths below 500 metres, we will have an idea of the accuracy of our method.

We see, further, that by far the greater part were caught at a depth of 300 metres, where we generally had out a ¾-metre silk net, whereas at 150 metres and at 500 metres the appliance used was, as a rule, a young-fish trawl, that would have had a far greater capacity for catching these fish. It seems, accordingly, that a preponderating majority of the individuals of this species are very strictly limited to an " intermediary " layer, situated at a depth of about 300 metres. A closer investigation of the individuals captured at a depth of 150 metres shows that they were all caught at night. This may be due either to an upward nocturnal wandering or to chance, though on this question the small amount of our material makes it unsafe to hazard an opinion: in subsequent investigations, however, it will be worth while taking this fact into consideration. Among the individuals captured at 500 metres there must, at any rate, be a few that were taken in the process of hauling in the young-fish trawl through the intermediary layer above, though the majority probably lived at that depth—a deduction supported by the fact that far fewer specimens were found in the young-fish trawl towed at 1000 metres, which may have been captured while hauling in.

This instance gives us a good illustration of our method, with its deficiencies and advantages. It is obvious that the greater the number of individuals we have to deal with, the greater is the probability of obtaining reliable information, and the safer are the conclusions we can deduce from our results. When, therefore, in what follows, I proceed to give some instances of the distribution in depth of different kinds of fish, I will begin by mentioning the commonest, or, at any rate, the most numerously captured forms belonging to the species *Cyclothone microdon* and *C. signata*.

Of these two species we caught altogether over 7500 individuals, which were all measured and arranged according to their length and the instrument in which they were captured, so as to also obtain information regarding the occurrence of the different sizes at different depths. In Fig. 16 I give, in the case of both species, the results of the catches made between Newfoundland and Ireland.

Cyclothone microdon was found during the cruise of the *Michael Sars* in the Northern Atlantic at every station where an appliance was towed in depth below 500 metres. Above 500 metres it was only met with occasionally. At a depth of 300 metres we only came across *one* individual. In depths from 500 metres down to 1500 metres its *quantitative* occurrence appears to be fairly uniform.

In our northern as well as in our southern section we found

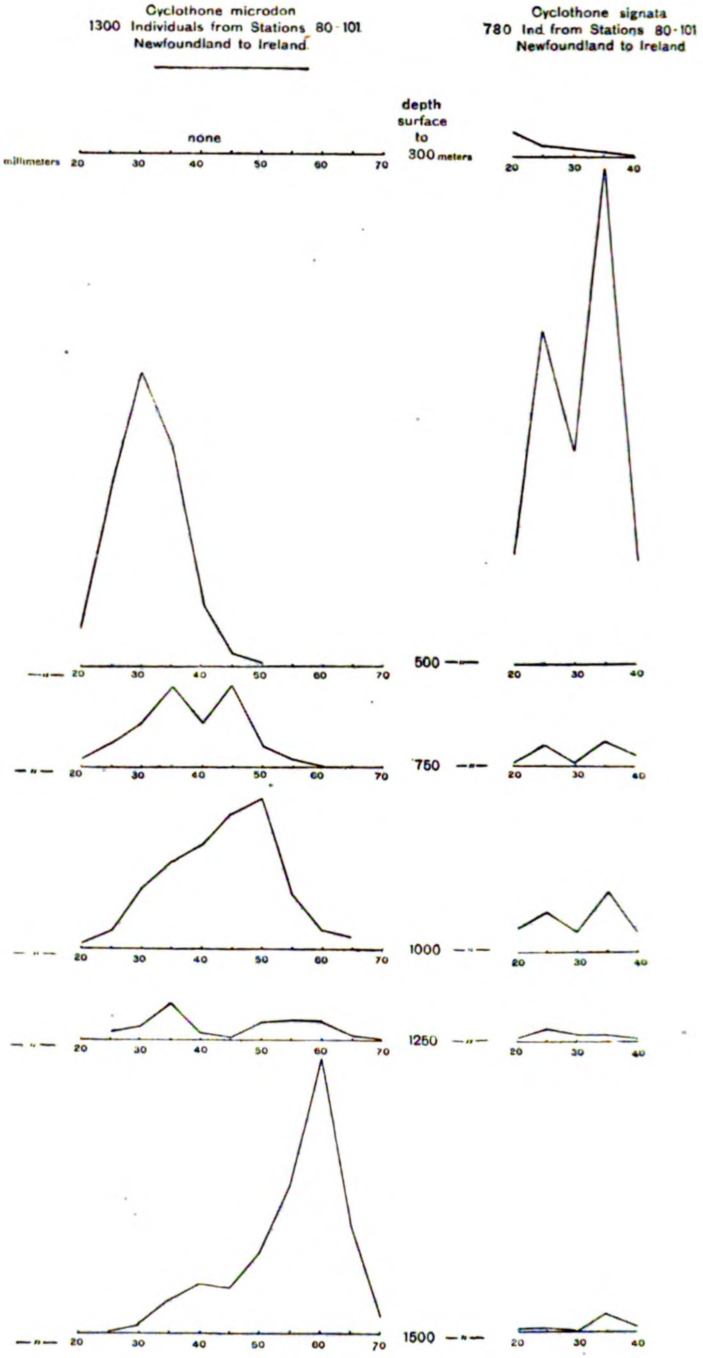


Fig. 16

RESULTS OF CATCHES BETWEEN NEWFOUNDLAND AND IRELAND.

approximately the same number of individuals in each of the three young-fish trawls, which we towed simultaneously, viz. at depths of 500 metres, 1000 metres, and 1500 metres. At depths below 1500 metres we only made a few hauls, though, on the other hand, we carried out some vertical hauls, which allow of a comparison between the quantity met with above and below 1500 metres. At station 63 (in the northernmost portion of the Sargasso sea) we secured 10 individuals in a haul from a depth of 4500 metres up to 1500 metres, and 27 individuals in a haul from 1350 metres up to 450 metres. Accordingly, seeing that the first haul was made through a distance more than three times as great as that of the second, we get the result that there were nine times more individuals in the intermediary layer from 1350 metres up to 450 metres than below 1500 metres. A more complete analysis of the different depths from 1500 metres down to the bottom of the sea (about 5000 metres) would have been very desirable, but, unfortunately, we were unable to spare time for it. It may be that there is a layer at the lowest depths where there are no individuals ; and I, for my part, at any rate, cannot help believing that the profoundest deep is far more poorly supplied than the intermediary layer.

If we next examine the size-distribution at the different depths, we shall see that it is perfectly clear that the smaller sizes are met with much higher up than the larger ones, which latter are mainly to be found at a depth of 1500 metres. In the northern section we find that at a depth of 500 metres the greatest number of individuals were 30 mm. in length, whereas at 1500 metres the majority attained 60 mm. At a depth of 500 metres we only came across two that were over 50 mm. in length.

The smaller and younger individuals, of a length of 20–30 *mm., live, accordingly, to a preponderating extent,* 1000 *metres higher up in the water-layers than the majority of the largest and oldest individuals.*

Whether in our material there are still smaller individuals from other depths we have not yet had time to ascertain.

Another remarkable fact which strikes us when we study our catches is that *the average size of the individuals is much less at the same depth in the southern than in the northern section.* The graph (see Fig. 17) shows this. We see, for instance, that in the southern section, if we want to get individuals of an average size of 30 mm., we must fish 250 *metres further down* than we would in the northern section.

The vertical distribution of *Cyclothone signata* is very different from that of *C. microdon.* We have captured many individuals at a depth of 300 metres, at any rate, at our southern section. The bulk, however, were found at a depth of 500 metres. In the hauls made at greater depths, the quantity diminished so rapidly that we may assume a large portion of the catches to have been made during the process of hauling in, and that there is only a comparatively thin layer below 500 metres in which they live. In a vertical haul from a depth of 4500 metres to 1500 metres we caught no individuals of this species, but we secured three individuals, on the other hand, in a haul from 1350 metres to 450 metres.

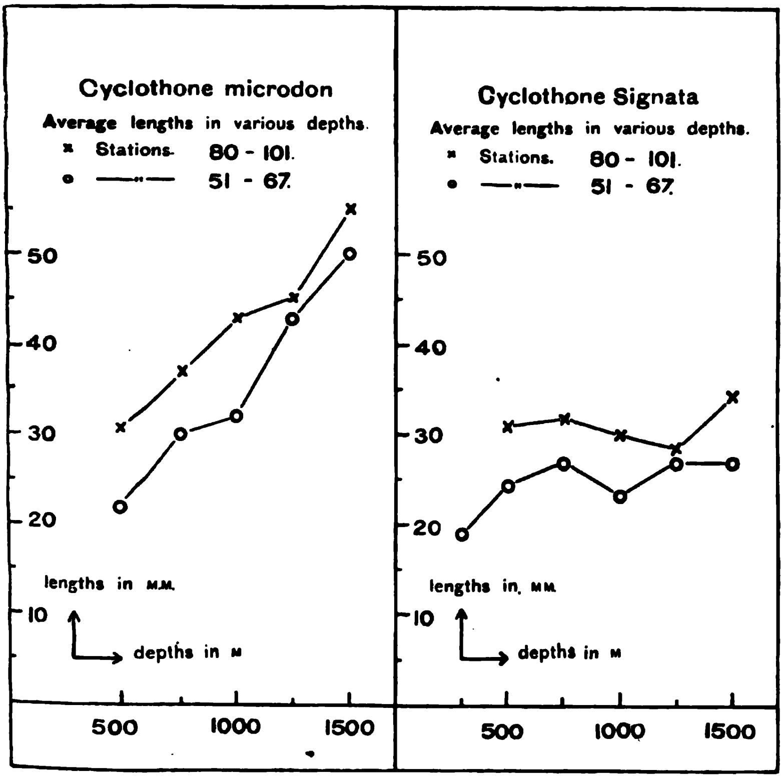
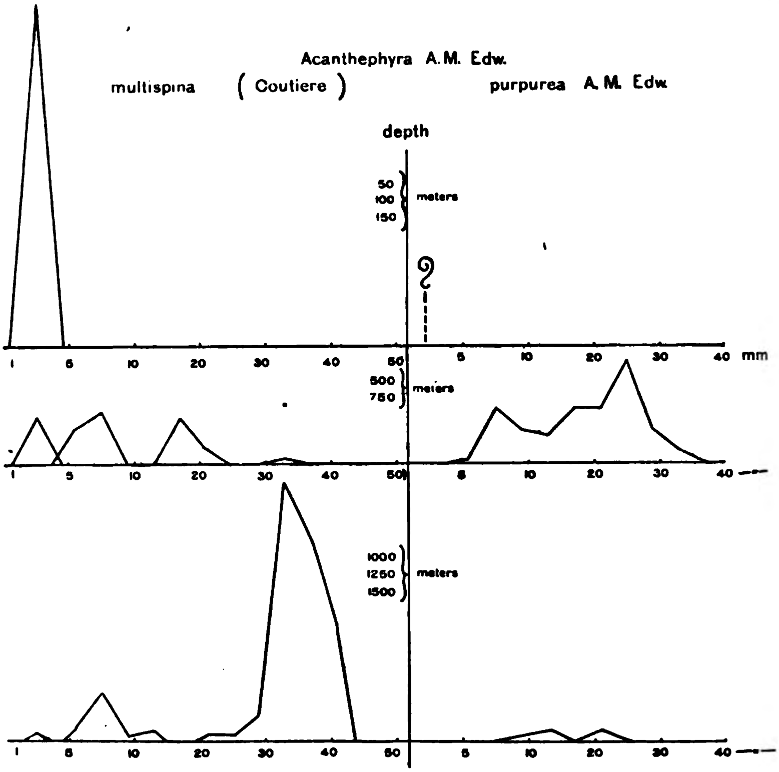


Fig. 17

Cyclothone signata is, accordingly, found in *an intermediary layer, with a maximum in the number of individuals at about* 500 *metres.* In the case of this species, too, we note that *the younger individuals are mainly to be found high up in the water* (notice particularly the southern stations), and that the same size is to be found deeper in the southern section than in the northern (see Figs. 16 and 17).

We have a remarkable parallel to the areas of vertical distribution of these two fish species in the case of the red prawn species. These latter unite with the black fishes in forming a populous and characteristic "community." We have come across no fewer than twenty-six species of prawns, of which we shall here refer to *Acanthephyra multispina* and *A. purpurea.*



Scale refers to length of Carapax

Fig. 18

Acanthephyra multispina shared with *Cyclothone microdon* the peculiarity of the largest and oldest individuals being found in the nets towed at the greatest depths, say, at 1000–1500 metres (see Fig. 18). At depths between 500 metres and 750 metres we met with middle-sized specimens; and in the upper layers, at from 50–150 metres, we found the larvæ. These larvæ were taken in quantities, whereas formerly only a single individual was known, namely, one which belonged to the collections of the Prince of Monaco. The specimen found previously had been described by Coutière as *Hoplocasicyphus similis*, but this has now been identified as a larva of *Acanthephyra multispina*.

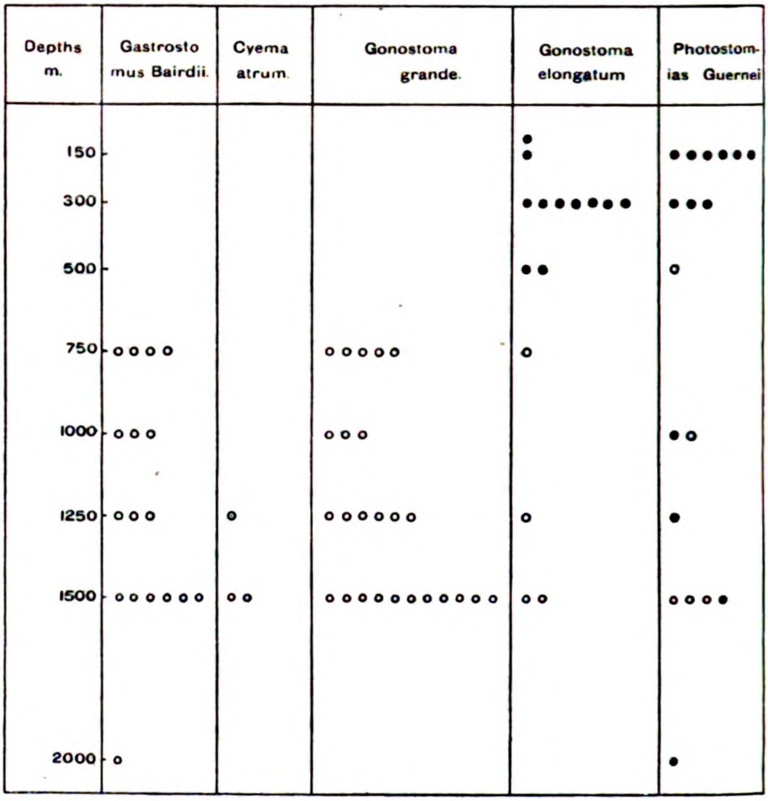
Acanthephyra purpurea resembles *Cyclothone signata*, in that its distribution is chiefly confined to an intermediary layer between 500 metres and 750 metres in depth. Our appliances at greater depths captured so few individuals, that we may safely assume even these to have been caught during the process of hauling in. A vertical haul at station 63, from a depth of 4500 metres to 1500 metres, yielded 5 individuals of *A. multispina*, but none of *A. purpurea;* while another haul from 1350 metres to 450 metres gave us 2 *A. multispina* and 33 *A. purpurea*. The larvæ of the latter have not yet been met with in our material, though they will probably be found in the higher layers of water, just as is the case with *A. multispina*.

What has just been said illustrates the conditions on the northern section from Newfoundland to Ireland, and if we examine the material from the stations farthest south in the Sargasso sea, we are confronted with exactly the same difference that we encountered in the case of the species of Cyclothone, namely, that the same forms descend to greater depths in the south than they do in the north. The larger individuals of *Acanthephyra purpurea*, for instance, occur at depths between 500 and 750 metres in the northern section, whereas in the south they were not captured by the net towed at 500 metres, though present in large numbers at a depth of 1000 metres. The intermediary layer in which these animals live is thus there situated several hundred metres deeper, just as we found to be the case with Cyclothone.

The instances I have given show the utility and exactness of our method of working. Where we have to deal with catches of great numbers of individuals, our errors and inaccuracies will undoubtedly be very small. The catches which the *Michael Sars* made of such forms as Cyclothone and Acanthephyra were certainly most satisfactory in this respect. But when we come to the catches which the expedition made of rare forms, or forms more difficult to capture, then we are bound to own that the method of working even of the *Michael Sars* is not sufficiently effective. Still, it is interesting to examine a few of the results yielded by the method we employed, with the object of discovering some conformity, or some general rule for the peculiar distribution of the different organisms at different depths.

I will commence with the view I formed during the cruise itself from the appearance of the catches on board, which view I find has also, to a certain extent, forced itself upon other observers, chief amongst whom I may mention Professor A. Brauer, to whom was confided the treatment of the fishes of the *Valdivia* expedition. I found on examining the catches from great depths that the black and dark-red forms were the all-prevailing ones among animals from the greatest depths.

I have not yet been able to examine the whole of the material with the object of ascertaining whether this is an invariable rule, but I will put forward here a few instances of what we found. Fig. 19 shows the vertical distribution of a number of black-coloured pelagic fish. These fishes are few in number, though they might be termed numerous, if we take into account what was previously known concerning "rare" forms. As will be seen, *Gastrostomus Bairdii*, *Cyema atrum*, and *Gonostoma grande* were only caught at depths from 750 metres downwards. The two species *Gonostoma elongatum* and *Photostomias Guernei* were caught in deep as well as shallow water, even in some cases as high up as 150 metres below the surface. The rule, then, that the black forms are only to be found at great depths, cannot be said to hold good universally.



Depths m.	Gastrostomus Bairdii.	Cyema atrum.	Gonostoma grande.	Gonostoma elongatum	Photostomias Guernei
150				● ●	●●●●●●
300				●●●●●●●	●●●
500				●●	○
750	○○○○		○○○○○	○	
1000	○○○		○○○		●○
1250	○○○	○	○○○○○○	○	●
1500	○○○○○○	○○	○○○○○○○○○○○	○○	○○○●
2000	○				●

Fig. 19

VERTICAL DISTRIBUTION OF BLACK-COLOURED PELAGIC FISH.

The question, accordingly, arises whether among the black forms there may not be said to be groups or different types. In common with several previous observers, I have been struck by the fact that even the anatomical structure of the black fishes points to different modes of living. If we compare, for instance, the pictures of the above-mentioned five species of fish, we will see that of the three species which were only found at great depths, *Gastrostomus Bairdii* and *Cyema atrum* are quite without light organs, and *Gonostroma grande* has only small ones, as is also the case with *Cyclothone microdon*. In *Gonostoma elongatum* and *Photostomias Guernei* the light organs are much more highly developed (as is also the case with *Cyclothone signata*). It is an interesting fact now to notice that every single individual of these two species which was captured higher up than 500 metres, was caught *at night*, which coincides with previous observations regarding black forms such as *Idiacanthus* and *Astronesthes*, which have been caught at night right close up to the surface. We may assume, accordingly, that among the black deep-sea fishes there are several different modes of life; that is to say, several different "biological types."

With a view to a better understanding of the occurrence of these black and red types in the sea,. I have endeavoured to compare their vertical distribution with the intensity of the sunlight in different depths and at different parts of the ocean.

We have seen that the upper limit for *Cyclothone microdon* and the red crustaceans, in the northern section from Newfoundland to Ireland, or about 50° N. lat., was approximately 500 metres below the surface; and we have also noticed that the limit of depth for the same forms at the southernmost stations, or about 33° N. lat., was some 200–300 metres deeper. In the Norwegian sea I have previously investigated the intermediary pelagic fauna, and found pelagic red prawns as well as the dark-red fish *Sebastes norvegicus* at depths of about 200 metres below the surface. Sebastes was taken, for instance, with floating long lines in considerable quantities on a course Jan Mayen-Lofoten—that is to say, in about 67° N. lat., at a depth of 200 metres—and it was even found, though in decreasing quantities, higher up. Along the Norwegian coast, in the fjords and sounds, we have a particularly rich fauna of red crustaceans (especially *Pandalus borealis*), occupying depths whose upper limit in the north, at any rate, may be put at above 200 metres. Now, if we calculate the depth to which the rays of the sun penetrate, after passing through the same distance in the water, assuming always that the rays are direct, and that the rate of absorption is the same, we find that the rays will have passed through the same distance to reach a depth of 500 metres in 50° N. lat., that they will pass through to reach 650 metres in 33° N. lat., or 300 metres in 67° N. lat.

However, the transparency of the water varies greatly in different regions. If we take the results of previous observations during different expeditions, we may set down the visible depth in the open sea as being roughly 50 metres in 33° N. lat., 40 metres in 50° N. lat, and 25 metres in the Norwegian sea in 67° N. lat.[*] Taking this into consideration, we find that there will be the same *intensity* from the rectilinear rays—

In 33° N. lat., at about 800 metres' depth.
,, 50° ,, ,, 500 ,, ,,
,, 67° ,, ,, 200 ,, ,,

The red and black animal forms, therefore, as has been found in the investigations I have just described, have an *upper limit* in the different waters which corresponds everywhere with the *same intensity of light*.

During the Atlantic cruise of the *Michael Sars* we undertook a series of measurements of the intensity of light with a photometer constructed by Dr. Helland-Hansen; to determine the intensity of the different colour rays, Dr. Helland-Hansen made use of panchromatic plates and gelatine colour-filters. The observation south and west of the Azores (that is to say, at the southern stations) showed that the rays of light strongly affected the plate at a depth of 100 metres. The red rays were weakest here, while the blue and violet rays were strongest. At a depth of 500 metres the rays from the blue and violet part of the spectrum were still distinctly visible, and at a depth of 1000 metres the violet or ultra-violet rays were yet perceptible. In 1700 metres, however, there was not the faintest trace

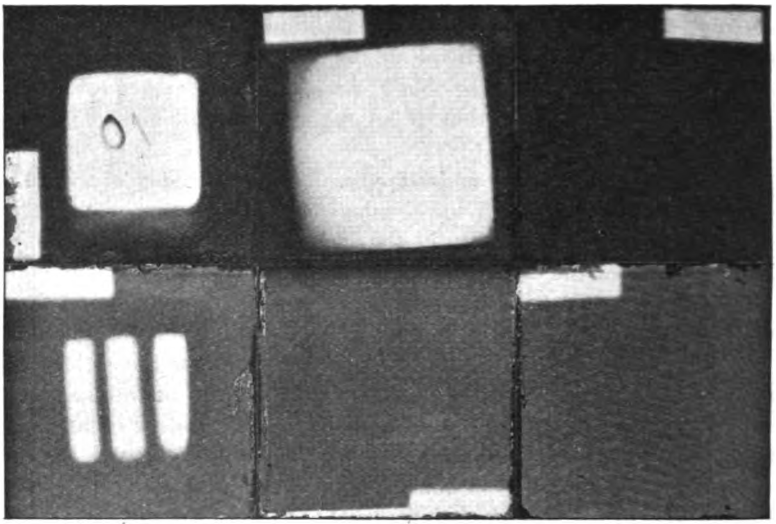


Fig. 20

PHOTOGRAPHIC PLATES FROM VARIOUS DEPTHS.

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[*] In coastal waters the transparency must be less than in the open sea, and it must vary with local circumstances. Special investigations will therefore to a great extent be needed in this new line of research.

of light, even after the plates had been exposed for two hours in broad daylight.

Fig. 20 shows some of the photographic plates exposed in Dr. Helland-Hansen's apparatus. The top row is from station 51. The left corner plate in this row is from 500 metres, exposure 40 minutes; the middle one from 1000 metres, exposure 80 minutes; the right one from 1700 metres, exposure 120 minutes. The lower row is from station 55, all plates from 500 metres and all exposed for 40 minutes. The plate to the left was taken without colour-filter; the middle one was taken with a blue colour-filter; the right one was taken with a green colour-filter. According to experience, the blue filter requires an exposure six times as long as a plate without a filter; the green filter eighteen times as long. On the middle one a faint roman V can be seen; on the right there is no trace of influence of the light.

In the above-mentioned depth, which denotes the upper limit for the black and red forms during the daytime, we may after this, no doubt, assume that there are only to be found chemically effective rays from the violet portion of the spectrum. Now, seeing that the coefficient of absorption for the red rays, as compared with the violet, is about in the proportion of 30 to 1, and that our observations failed to trace any red rays at a depth of 500 metres, it follows that *the red animals at this depth must be quite as invisible as the black ones.* It is interesting to note in this connection that it is only at night that the black fish with large light organs are found high up in the water, and that red crustaceans in the arctic regions, as was noticed by Scoresby in the case of *Hymenodora glacialis*, are to be found right up to the edge of the ice at the surface of the sea.

Above the region I have hitherto been describing, with its black and red forms, our parallel hauls have shown us an equally characteristic though very different group of pelagic fishes. Their peculiarity is that their body is always more or less *compressed laterally*. In colour they are *dark along the back and silvery or shining, with a bluish-violet gleam along the sides, their eyes are large, and often telescopic,* and most characteristic of all, I suppose, are their strongly developed light organs; characteristic forms are especially to be met with among the families *Sternoptychidæ* and *Stomiatidæ.*

Fig. 21 shows the depth at which a number of these forms occur. It will be seen that 500 metres may be taken as their *lower* limit, and that *the greatest number of individuals live at a depth of* 300 *metres;* above 150 metres there were only a few found, and even those that were met with in 150 metres, or higher up, were with very few exceptions taken *at night.*

Cyclothone signata may be said to approximate to this group, as far as distribution is concerned; and this form also has large, well-developed light organs. A closer analysis of the occurrence of these forms in different latitudes would probably reveal much of interest, though this must be reserved for subsequent investigations.

It is important to lay stress upon the fact that these *shining colours,*

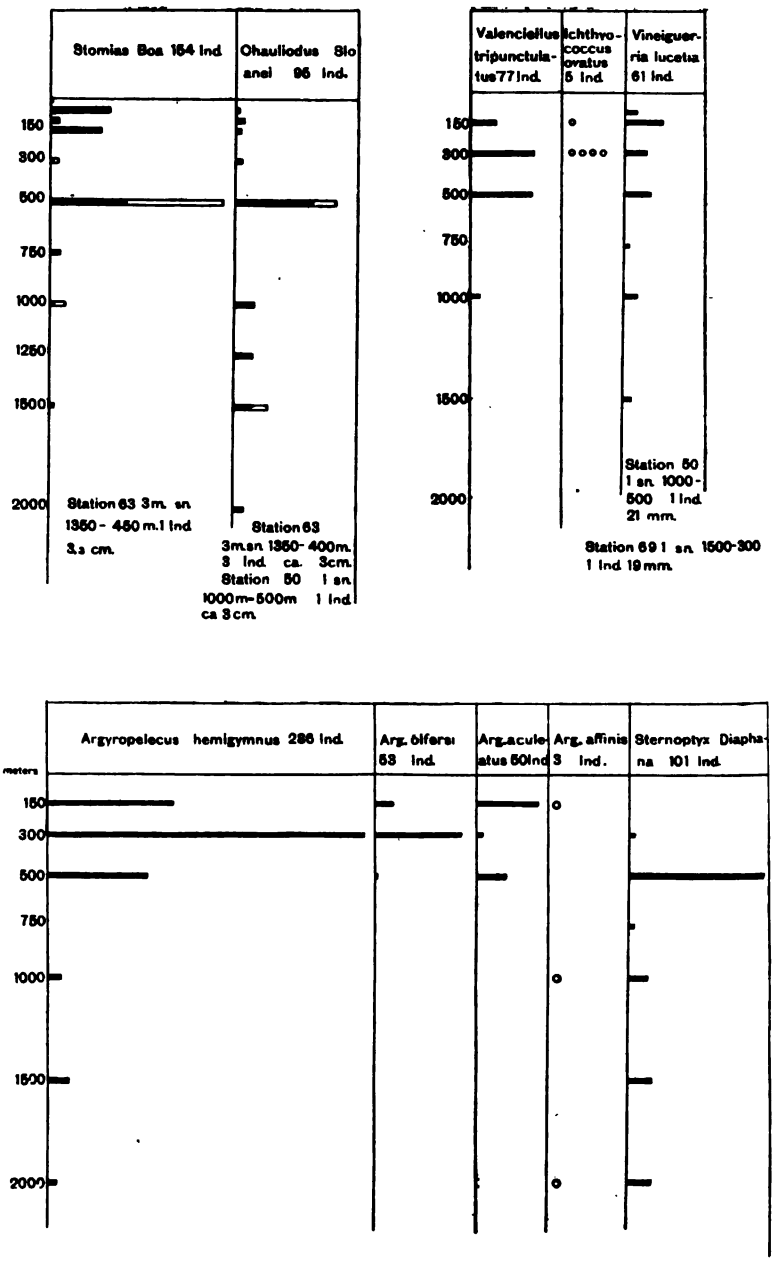

Stomias Boa 154 Ind
Chauliodus Sloanei 96 Ind.
150
300
500
750
1000
1250
1500
2000
Station 63 3m. sn 1350 - 450 m. 1 Ind 3.3 cm.
Station 63 3m. sn 1350- 400m. 3 Ind ca. 3cm. Station 50 1 sn. 1000m-500m 1 Ind ca 3 cm.
Valenciellus tripunctulatus 77 Ind.
Ichthyococcus ovatus 5 Ind.
Vineiguerria lucetia 61 Ind.
Station 50 1 sn. 1000-500 1 Ind. 21 mm.
Station 69 1 sn. 1500-300 1 Ind. 19 mm.
meters
Argyropelecus hemigymnus 286 Ind.
Arg. Olfersi 53 Ind.
Arg. aculeatus 50 Ind
Arg. affinis 3 Ind.
Sternoptyx Diaphana 101 Ind.

Fig. 21

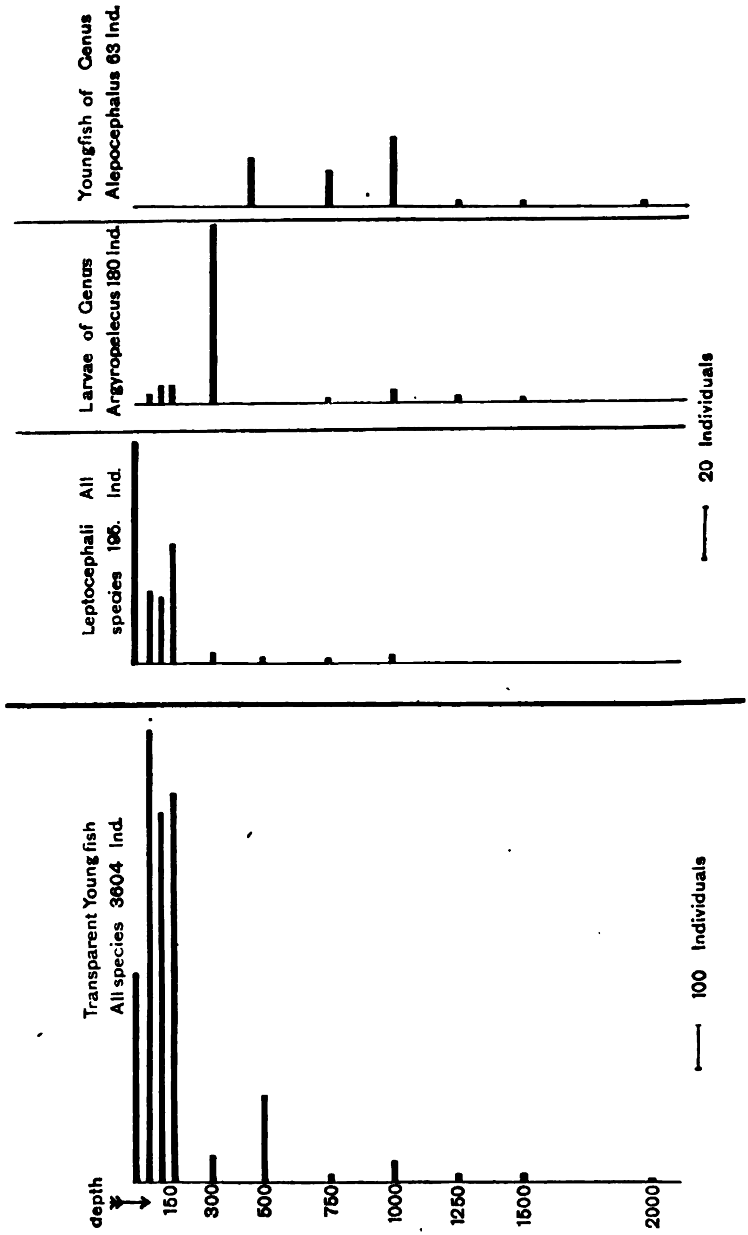
remarkable light organs, and peculiar telescopic eyes do not belong to the dark region in the sea, where the sunlight never penetrates, but, on the contrary, to a region where there are, at any rate, *considerable quantities of the rays which are nearest to the blue, violet, and ultra-violet portion of the spectrum.*

There has been a good deal of discussion as to whether the light emitted by the light organs was entirely produced by the vital energy of the organisms, or whether the organisms had the power of *transforming* the ultra-violet rays of the sunlight into rays of lesser wave-length. The observations I have described here cannot, of course, decide questions of this kind, but they show, at any rate, that the organisms with light organs live in water-layers in which there are quantities of rays from the sun. And we recognize, further, in these forms a new biological type of organisms, a separate group with quite characteristic outward conditions of existence.

It is well known that a great number of the bottom animals of the greatest depths have phosphorescent light. On our cruise we caught in the trawl from 5160 metres of depth an *Unbellula Güntheri* showing splendid phosphorescence. Are the large eyes of the "bottom fishes," for instance, the Macruridæ, to be explained by this light? It is at all events interesting that the *pelagic* fishes from the greatest depths have very small eyes, while the bottom fishes have eyes of the greatest size.

The higher up we ascend towards the surface of the sea, the more varied become the forms and colours of the organisms and the more diversified become also, probably, their conditions of life. I have so far only been able to examine a portion of the large mass of material from the uppermost water-layers, and will merely mention a single group from this region, namely, *the larvæ and young fish forms.* Of these we have collected a very large quantity, amounting to thousands. It has been impossible to determine them all, as this will be a long and laborious task.

Fig. 22 shows how out of 3600 transparent larvæ and young fishes, 90 per cent. were secured in the appliances operated from the surface down to a depth of 150 metres. These forms are young stages of many different kinds of fishes. There are the crystal-clear young of black fishes like *Gonostoma elongatum*, light-coloured young of a deep-living bottom fish like the genus Macrurus, of fish with large light organs like Vinciguerria, and the numerous species of Scopelids and of surface fishes (Caranx, Scombridæ, etc.). To this group belong also the Leptocephalidæ, whose depth-distribution, as will be seen, quite corresponds with the other transparent larval forms. Two groups of larvæ and young fish have so far been found with a peculiar mode of life; one being larvæ of the genus Argyropelecus, whose maximal occurrence corresponds with that of the grown forms, namely, at a depth of 300 metres, and the other belongs to the genus Alepocephalus. The grown forms of the latter genus are generally considered to be among the most pronounced of the deep-water fishes, and they have been taken with the trawl at great depths, or else pelagic at the lowest depths (by the *Michael Sars* amongst others). They are totally devoid of light organs. Larvæ with yolk-sac, as well as all stages of young fish of all sizes, have been found by the expedition in considerable quantities, the whole of which were taken *at depths from* 500 *metres down to* 2000 *metres*. It seems, accordingly, that these fishes from their earliest stages of develop-



Young fish from all Stations

Fig. 22

ment are denizens of the deepest regions. Johs. Schmidt[*] has previously found bathypelagic eggs of deep-sea fishes, but, as far as I know, not of this genus. Now, what makes these two groups of larval forms so remarkable is this, that *the larvæ of Argyropelecus* from a very early stage have *a shining appearance, and very large light organs*, whereas *the larvæ of Alepocephalus*—even while still with the yolk-sac—develop the *black pigment which characterizes the grown animal.* We have thus instances of how the peculiarities of colour (referred to previously) may occur even at the earliest period of growth, in cases where the young stages have the same characteristic depth-distribution as the grown individuals.

A very interesting and important question is the quantity of animals in the different depths. This question has not been much studied yet. I believe myself that the upper limit of the red and dark-coloured forms is particularly rich. In the Norwegian sea I found[†] that the occurrences of a rich intermediate pelagic life corresponded to a great rise in the density of the sea-water, and I explained this thus, that the food of the animal sinking down from the upper layers might accumulate there. The closer study of our material may give more information about this interesting question.

In my preceding remarks I have given a number of instances of the observations we were able to make regarding the depth-distribution of fishes, when we examine material collected by means of parallel hauls. But it is obvious, too, that this material may equally well be used for ascertaining their horizontal or geographical distribution, and it is only after studying simultaneously their vertical as well as horizontal distribution, that we can characterize the outward conditions under which they live. If we look at the horizontal distribution as found by the *Michael Sars* and compare it with previous observations in the Northern Atlantic, we shall get some idea of how little knowledge we possess concerning the most ordinary forms inhabiting the ocean between Europe and the coast of the United States. I will base my comparison entirely on Brauer's valuable summary of what was previously known, and on the same instances that I have employed when discussing the vertical distribution.

Black fishes and red crustaceans were caught at *all* the stations during the cruise of the *Michael Sars* in the Atlantic, wherever we lowered our appliances to greater depths.

Chart, Fig. 23, gives all these stations, and shows us accordingly at the same time the stations where *Cyclothone microdon* and *C. signata* were captured. It will be seen that these species are distributed everywhere from the Iceland-Shetland ridge to south of the Canary islands and to the Sargasso sea. It is interesting that these forms have never been found in the Norwegian sea. The Wyville-Thomson ridge seems to prevent the pelagic animals living deeper than 500 metres from migrating into the Norwegian sea, while the silvery fishes, like *Argyropelecus Olfersi*, living in 300 metres depth, have been found occasionally far north along the Norwegian coast. During the cruise we also secured the following species of the genus Cyclophone: *C. microdon, pallida, livida, acclinidens,* and *signata alba.* With the exception of the last-named, however, these were all caught at the *southernmost stations* of our cruise, and in exceedingly small quantities. They may therefore all be assumed to be *southerly forms.* The chart shows the places where *C. microdon* (□) and *C. signata* (+) were previously caught. *C. microdon* had been taken at quite a number of places, especially in the north, whereas *C. signata* had only been met with in a few localities, though they were found on this occasion by the *Michael Sars* in thousands, and distributed over the entire area investigated.

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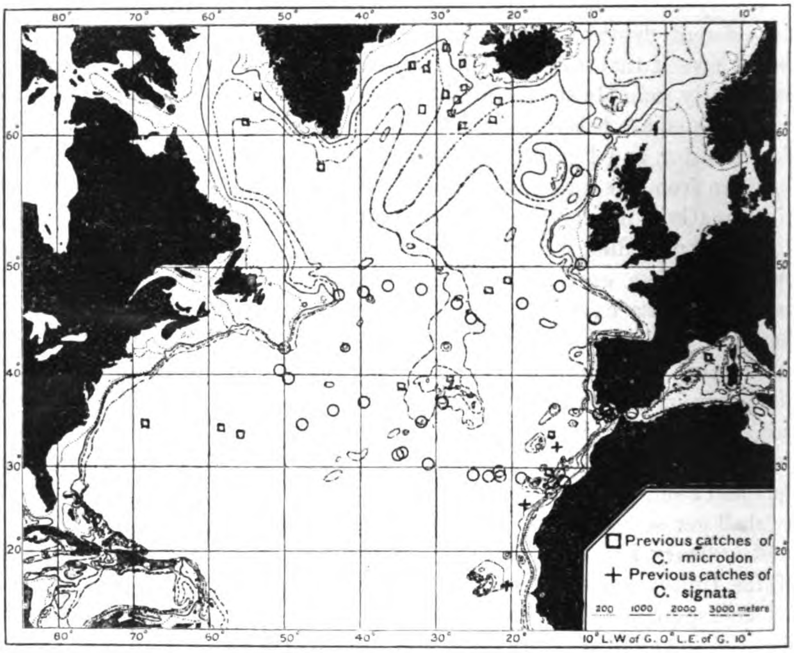
[*] See Johs. Schmidt, "Contributions to the Life-history of the Eel (*Anguilla vulgaris*, Flem.)." 'Rapport et Procès-verbaux du Conseil perm. intern. pour l'exploration de la mer,' vol. 5. Copenhagen: 1906.

[†] Johan Hjort, 'Die erste Nordmeer-Fahrt des norw. Fischereidampfer *Michael Sars*.' 1900. *Petermanns Mittl.*, Bd. 47. 1901.


80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
60
50
40
30
20
□ Previous catches of C. microdon
+ Previous catches of C. signata
200 1000 2000 3000 meters
10° L. W of G. 0° L. E. of G. 10°

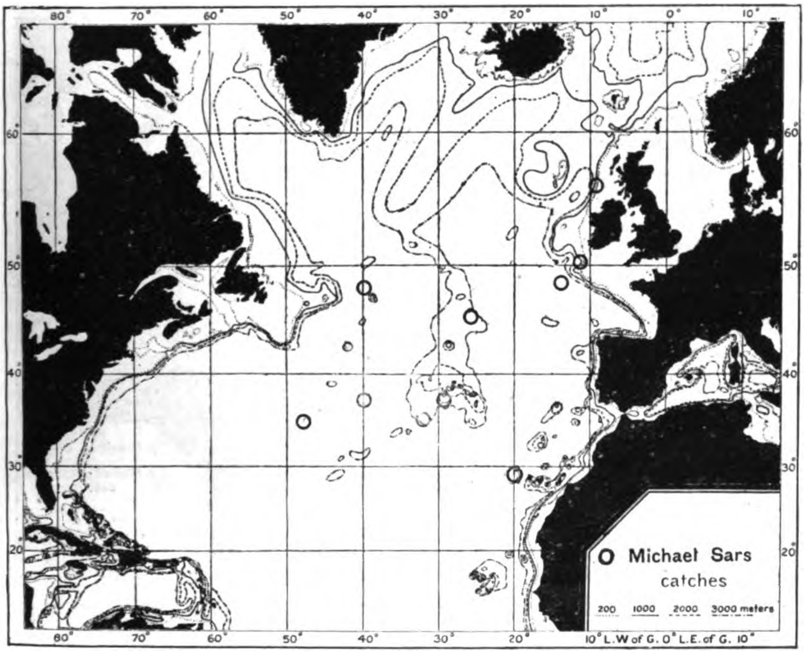
○Cyclothone Signata and microdon
caught by "Michael Sars"

Fig. 23

Gastrostomus Bairdii was previously caught by the *Albatross* on the slope off the coast of the United States and nowhere else. It was taken by the *Michael Sars* south of the Canary islands, between those islands and the Azores, and to the south and east of the Newfoundland banks. It therefore, apparently, is also to be found over the greater part of the Northern Atlantic, at any rate to the south and west of the Azores. A similar distribution is shared by *Photostomias Guernei,* which had previously only been taken near the Azores, and also the rare *Gonostoma* *grande* (Fig. 24); they were found over the whole area. Most interesting, too, are a number of very "rare" forms of the *Ceratiidæ*. We found at least eight species, of which I am inclined to believe five are new. One species (*Melanocetus Krechi*) had only once been previously found, a specimen having been captured in the Indian ocean. We secured two specimens to the south of the Azores.

The genera *Aceratias*, *Opisthoproctus*, *Malacosteus*, and *Cyema* afford interesting examples of rare deep-sea fishes that had previously only been taken singly or in localities remote from the course of the *Michael Sars*.

Of the group with large light organs, which we found in the intermediary layer at about 300 metres, we see that *Argyropelecus hemigymnus* and *A. Olfersi*, *Sternoptyx diaphana*, *Stomias boa*, *Chauliodus Sloanei* (Chart, Fig. 25), and *Vinciguerria lucetia*, occur over the whole or the greater portion of this vast area. These had formerly only been caught off the North American slope, on the coast banks of Europe or near the Azores, where most previous researches have been made.



Gonostoma grande

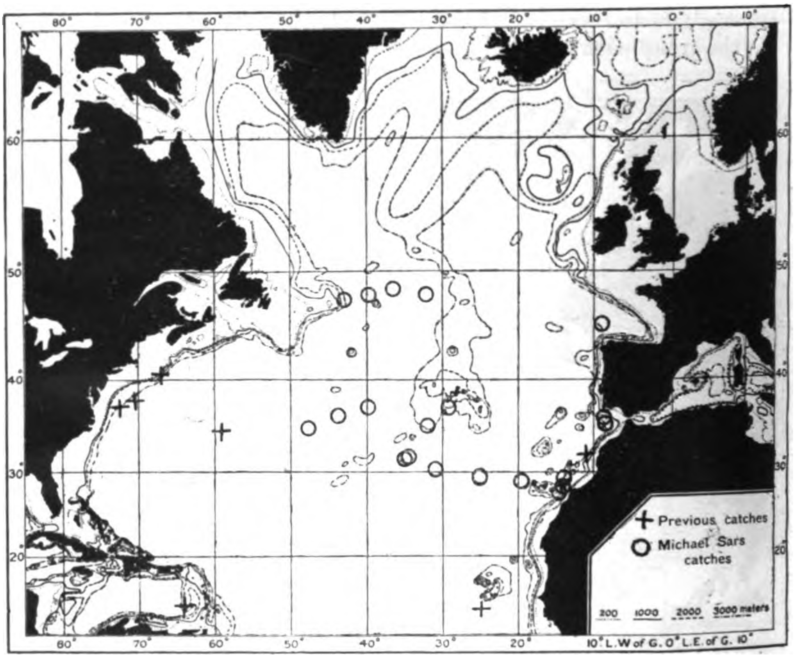
Fig. 24

Argyropelecus aculeatus and *A. affinis* were only caught at the southern stations.

Transparent young fish were captured over the whole area of investigation, though in very varying quantities. The chart (Fig. 26) shows their quantitative occurrence in three groups, namely, fewer than 100, between

100 and 250, and over 250. The largest quantities were taken south of the Azores, west of the Canary islands, and east of the Newfoundland banks. This great abundance of young fish a short distance beyond the slope of the coast banks is of the utmost interest. We shall only, however, grasp its full significance, when we have succeeded in determining all the numerous forms of which this large group is composed.

In the open sea over the greatest depths the Scopelidæ are undoubtedly the most numerous group among the young fish. We find also many extremely interesting forms with stalk eyes, telescope eyes, and so on. Amongst those with telescope eyes there are many of a perfectly transparent new form, which may in all probability be assigned to the genus Dysomma. They were mostly caught in the uppermost 150 metres.



Chauliodus Sloanei

Fig. 25

When we have succeeded in determining these young stages, we will be able to throw much light upon the life history of many important species of fish. The numerous forms of the group Leptocephalidæ will by no means be the least interesting among them. The 195 individuals that were found are believed to belong to no fewer than 20 species, of which a good many are entirely new.

I have previously (in *Nature* of November 24, 1910) published a short description of a number of these Leptocephalidæ, which we were able to prove to be the larvæ of the European eel. These larvæ (44 specimens in all) have this much of interest in them, as compared with previous finds, that they were met with right out in the Atlantic ocean, far away from the slopes where they previously had been discovered.* Two groups were come across in our material, of which one consisted of full-grown larvæ, the other of younger stages of development, the smallest being 41 mm. in length. These young stages were only found in the sea to the south of the Azores, a fact which gives rise to many questions regarding the wanderings of this remarkable species of fish; and this discovery will probably contribute its share towards the solution of the old problem about the eel's spawning grounds. We have also young fish of genera (to which belong important food-fishes) like Scomber, Clupea, Caranx, and others, but they have not yet been studied.

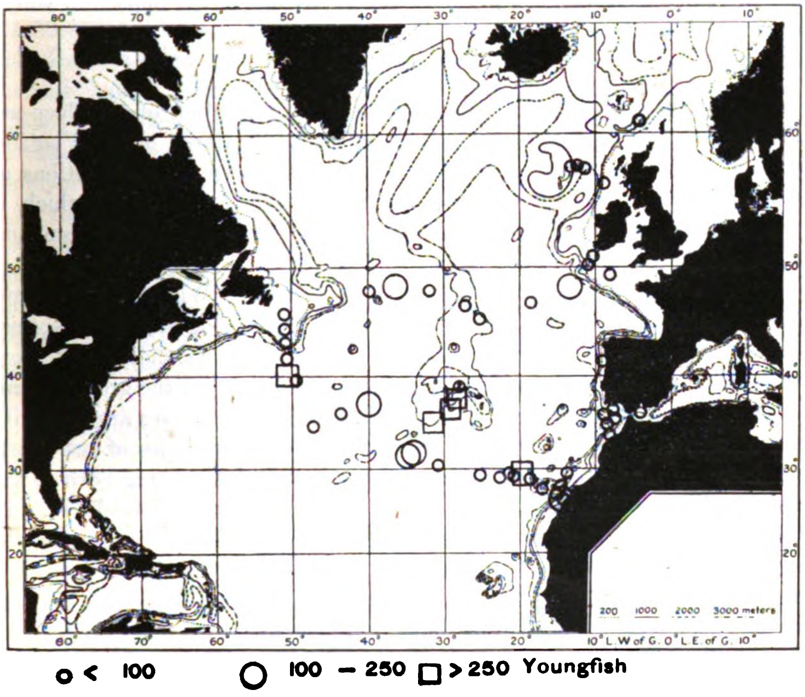


Fig. 26

It seems to me that these instances are sufficient to make it clear that the Atlantic offers a fruitful field for future investigations into the pelagic animal life of the ocean. I hope, also, that it will be conceded that the methods of work adopted by the *Michael Sars* expedition has yielded, and will continue to yield, wider and more reliable information regarding the geographical distribution of pelagic animal life, as well as concerning its biological conditions of existence. However, I feel bound to admit that our expedition was necessarily restricted in its mode of operations. Nor could it well be otherwise. Practical reasons forbade the use of more than a limited number of appliances, and no appliance can be adopted to catch all kinds of animals. If the *Michael Sars* succeeded in securing large quantities of certain forms, its catches of other forms were insignificant. We need unquestionably a new expedition, if we are to acquire more accurate information, especially with regard to the larger forms. It will be necessary, too, to make use of bigger and wider-meshed instruments, though even then I feel convinced that the method we adopted, of making many hauls simultaneously at different depths, will prove to be the most serviceable and the most likely to promote our knowledge of the depths in which the animals are living.

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* Schmidt, *loc. cit.*

TRAWLINGS.

Brauer has made out a statement of the distribution of the deep-sea fishes along the bottom of the sea, based on the material of the *Valdivia* expedition. He founds his interesting survey chiefly on observations of the distribution of different species of the genus Macrurus, which is generally regarded as a representative of the most typical bottom and deep-sea fish.

Brauer's principal conclusions are as follows: Whereas the genus Macrurus is distributed over all the seas of the world, particular species are very restricted in their areas of distribution. Secondly, not more than a few species are known to be common to several of the great oceans. This is due, in his opinion, to the fact that only a few species are met with far out from the coasts (or more strictly speaking, the slopes of the coast-banks). In any case we do not find the same species existing both in the neighbourhood of the coast banks and out on the deep ocean floors. To this he adds that the young stages of the genus Macrurus do not inhabit surface-layers, or layers whose movements would be likely to distribute them over considerable areas. "The fact remains that up to now no eggs or larvæ of deep-sea Macruridæ have been met with high up in the water." The various species are, therefore, comparatively local and adapted to peculiar conditions in a definitive restricted district.

This interesting view is, however, unsupported by conclusive proofs. We know as yet but little either regarding the propagation of deep-sea fishes, or about the physical conditions under which they live. I have mentioned above that we during our expedition have found various stages of the young of Macrurus in the uppermost 150 metres. Schmidt * has previously described bathypelagic eggs of this genus. Larvæ and young stages of the genus Alepocephalus were taken floating in the deep layers below 500 metres.

The plan I proposed for trawling, in combination with our hydrographical investigations, was to undertake a series of hauls at a number of localities from the coast banks over the slopes, and down to the deep ocean floor. In the twenty-four hauls made by the *Michael Sars* we succeeded in carrying out three such series: one from the south-west coast of Ireland, one in Cadiz Bay, west of Tangier, and one to the south of the Canary islands. We also made a few hauls at great depths in the Bay of Biscay, between the Canary islands and the Azores, and to the north of the Azores.

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* Schmidt, *loc. cit.*

The large mass of material collected is still only partially examined, so that I am obliged to have recourse to the notes made on board at the time. However, these are perhaps sufficient to justify me in mentioning a few particulars, which will give a fairly good idea of some of the results.

For trawling we used a large otter-trawl, of the usual construction, with 50-feet headrope. It took a good deal of practice to lower this large appliance down to great depths, but we succeeded, and made some excellent hauls, which yielded extremely satisfactory catches, especially of fishes; and the material thus collected furnishes a good illustration of the fish fauna, even if nothing essentially new was caught in the way of unknown types.

In the shallower waters—down to a depth of 200 fathoms—the fauna proved for the most part, as was already known, very different in the three series. The following are a few examples from the catches, the list of the names being taken from a preliminary determination on board. In the case of the Sparidæ we were unfortunately not able to determine the specimens on board.

Off the Irish Coast. 100 fathoms.	Bay of Cadiz. 90 fathoms.	West of Africa 26° N. 150 fathoms.
1 Gadus æglefinus.		
8 ,, poutassou.		
5 Merluccius vulgaris.	52 Merluccius vulgaris.	10 Merluccius vulgaris.
1 Phycis blennioides.		250 Sparidæ.
40 Gadiculus argenteus.		
3 Solea vulgaris.	1 Solea vulgaris.	Many Centriscus scolapax.
170 Zeugopterus megastoma.	Mullus surmuletus.	1 Mullus surmuletus.
	Centrodontus pagellus.	
	Sparidæ.	
5 Arnoglossus lophotes.		
2 Caranx trachurus.	8 Caranx trachurus.	2 Caranx trachurus.
12 Trigla gurnardus.	2 Trigla gurnardus.	
80 ,, cuculus.	16 ,, cuculus.	1 Trigla cuculus.
5 Callionymus.	25 ,, hirundo.	Many Trigla hirundo.
2 Capros aper.	30 Capros aper.	Few Capros aper.
4 Lophius piscatorius.	4 Zeus faber.	1 Peristedion.
4 Argentina silus.	1 Peristedion.	5 Argentina silus.
8 Acanthias vulgaris.	4 Acanthias vulgaris.	5 Acanthias vulgaris.
5 Scyllium canicula.	4 Scyllium canicula.	1 Scyllium canicula.
25 Raja clavata.	Raja sp.	25 Raja sp.
1 ,, circularis.		2 Rhina squatina.
1 ,, oxyrhynchus.		

It will be seen from these and other hauls that a number of forms are common to all the series from Ireland down to 26° N. lat., such as, for instance, ***Merluccius vulgaris*, *Solea vulgaris*, *Arnoglossus lophotes*, *Caranx trachurus*, *Trigla cuculus*, *Capros aper*, *Argentina silus*, *Acanthias vulgaris***, and ***Scyllium canicula***.

The Gadidæ present the most striking difference, being represented by a large number of species off the west of Ireland, but merely by ***Merluccius vulgaris*** from Cadiz Bay southwards. This last fish is shown by the catches of the trawlers to be still very plentiful along the west coast of North Africa.

The abundance of Sparidæ, Mullidæ and Triglidae, from shallow water down to 150 fathoms, is typical of the southernmost series. These light-red or silvery forms constitute the bulk of the catches made by the fishermen of the Canary islands upon the African coast, and they give the whole fish fauna its distinctive character. During our stay on the African coast we were able to watch the fishermen catching different kinds of Sparidæ, and I have rarely seen a handline-fishing yield such excellent results. I shall describe this subsequently at greater length, when our material has been completely examined.

That the fauna, down to a depth of 200 fathoms, must vary in character in the long stretch of sea from the Wyville-Thomson ridge to the north of Africa, is natural enough. The chart in Fig. 4 shows that salinities and temperatures vary considerably at this depth. South of the Wyville-Thomson ridge we have a temperature of 8° C., off the south-west coast of Ireland we get 10° C., in Cadiz Bay over 12° C., and nearly 14° C., southwards of the Canary islands.

At *a depth of* 500 *fathoms* the position of affairs is different. For, as will be seen on the chart (Fig. 2), we get the same temperature of 7°–8° C. immediately south of the Wyville-Thomson ridge that we get to the south of the Canary islands. The Bay of Cadiz alone forms an exception, since the temperature there rises to 10°, owing to the influence of the warm water which streams out from the Mediterranean. In 500 fathoms, accordingly, we find a very uniform fauna. I give below a few instances; the Macruridæ are not yet determined.

South of Ireland. 500 fathoms.	Bay of Cadiz. 700 fathoms.	Africa, 28° N. Lat. 740 fathoms.
24 Coryphænoides.		
160 Macrurus.	11 Macrurus.	Many Macrurus.
16 Trachyrynchus Murrayi.	19 Trachyrynchus Murrayi.	4 Trachyrynchus Murrayi.
31 Lepidion eques.		
70 Mora mora.	36 Mora mora	4 Mora mora.
1 Antimora viola.		
1 Halosaurus.	3 Halosaurus.	
9 Alepocephalus Giardii.	4 Alepocephalus Giardii.	5 Alepocephalus Giardii.
3 Hoplostethus Mediterraneum.		
3 Scorpæna echinata.	1 Bathypterois.	10 Bathypterois.
3 Synaphobranchus.	1 Synaphobranchus.	Many Synaphobranchus.
8 Chimæra mirabilis.		
1 Raja nidrosiensis.		

Although this list must necessarily remain incomplete until all the forms have been fully determined, it illustrates the striking uniformity of the fauna on the slopes of the coast banks from 60° N. lat. right down to 28° N. lat.

Some years ago I made two series of trawlings to the south and north of the ridges which separate the Norwegian sea from the Atlantic, running from Iceland to the Faroes and Shetland. In a review of our fishing investigations* Dr. Appellöf has compared the invertebrate fauna of the two series, and I have treated the fishes. Our research gave the following result: to the south of the ridges we found some species which did not occur to the north of the ridges, *i.e.* in the Norwegian sea. Then we found some which also are distributed in the boreal and boreoarctic areas of the Norwegian sea. This applies to invertebrates as well as to fishes which live in the Norwegian fiords, on the coast banks and the upper part of the slopes towards the deep basin of the Norwegian sea.

In the deepest parts of the Norwegian sea, however, where the temperature is quite low (under 0° C.), there is a fauna of Arctic character, which is entirely lacking in the Atlantic.

The Danish zoologists, Professor Jungersen and Dr. Ad. Jensen, have especially shown this latter fact in all details. The previous investigations of the *Michael Sars* have also contributed towards the knowledge on this subject, and during the Atlantic cruise of 1910 some very successful hauls were made in deep water (1000–600 fathoms), south and north of the Wyville-Thomson ridge. The material obtained confirm our previous experience as to the character of the fauna in the two areas in regard to fishes as well as to invertebrates (*e.g.* echinoderms).

To operate the big trawl at the greatest depths of the North Atlantic, in about 2500 or 3000 fathoms, proved a very difficult task. However, two of our hauls were quite successful. The first was in the Bay of Biscay, at a depth of 2500 fathoms. Our catch contained a number of invertebrates, including holothurians of the genus *Elpidia*, Alcyonidæ, sponges, and ascidians, and two fishes belonging to the genus Macrurus.

The second haul, between the Canary islands and the Azores, at a depth of 3000 fathoms, yielded only a very few living organisms. In the half-barrel of mud brought up by the trawl, we found 30 pumice-stones, overgrown with Stephanocyclis and Limopsis, and there were also two holothurians (*Lætmogone violacea* and *Elpidia, sp.*), Sertularisæ, fragments of an Umbellularia, an Antipathes, a spike of a Cidaris, fragments of shell of Argonauta, as well as one Bulla tympanica of a whale, and two sharks' teeth, of which the first belonged to a Carcharodon, and the second to an Oxyrhina. Of fishes there were one Malacosteus, one Alepocephalus, one Leptocephalus, one Argyropelecus, and a form not yet determined. All these fishes I believe to have been pelagic, and to have been taken during the process of hauling in. Regarding one form alone there was doubt

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[*] Norsk Havfiske, *Norges Fiskerier*, I. Bergen: 1905.

whether to class it as a bottom fish or as pelagic, namely, an unquestionably new species much resembling *Ipnops Murrayi*.

Judging from the appearance of the trawl when being lowered and when being afterwards hauled in, I consider this haul to have been, technically speaking, a success, and I cannot explain the catch otherwise than by supposing that *at those profound depths there was a poverty of animal life*. It remains a question whether all these great ocean floors are equally barren in regard to animals, and especially fishes. So far as I know the literature on the subject only records the capture of a few Macruridæ from the greatest ocean deeps, this being all the evidence that there is to favour belief in the occurrence of larger fish there. But is it perfectly certain that even those are not also pelagic ? On several occasions during the cruise our tow-nets captured over the greatest ocean depths pelagic specimens of Alepocephalus, which is generally brought up by the trawl (see the catches from 500 fathoms). In any case the animal life there must be extremely scanty. And this is borne out by the vertical hauls with our big net, below 1500 metres, which I have referred to when discussing *Cyclothone microdon*.

The few instances from our trawlings that I have given here are perhaps insufficient for a complete illustration. A fuller examination of the material will certainly reveal more. But what I have said in this and the preceding sections of my lecture will, at any rate, make clear to you the aims and method peculiar to this expedition, and will, I hope, be of value for planning further investigations in the interesting marine area which formed our field of operations.

The PRESIDENT (before the paper): In the announcement of the lecture to-night two names appear, those of Sir John Murray and of Dr. Hjort; but the lion's share of the lecture will, as I understand, in truth, fall to our distinguished foreign guest, Dr. Hjort. In his discourse he will describe the oceanographic researches which have been made on board the steamer *Michael Sars*, a steamer which was built by the Norwegian Government especially for this class of scientific work. Dr. Hjort is amply qualified to speak on all the subjects he will touch on to-night. He was for some years a lecturer in Zoology in Christiania. Since the year 1893, he has been engaged in fishery investigations, and since 1900 he has been the Government Fishery Director for Norway and in command of this *Michael Sars* steamer—a steamer which has been employed frequently in the North Sea and in the eastern parts of the Atlantic. The record of the work done is one of which he may well be proud. As to the other name, that of Sir John Murray, I think Dr. Hjort will tell us all about his connection with this expedition, and I will at once, therefore, call on the lecturer to address us.

Sir JOHN MURRAY (after the paper): Some ten or twelve years ago, Dr. Hjort did me the honour to say that he was a pupil of mine, but during the last eighteen months I think I can pretty well say I have been a pupil of Dr. Hjort's. We have often discussed together the problems of the deep sea, and owing to the interest which the Norwegian Government takes in deep-sea investigation, we were able to plan this little cruise during 1910. From what Dr. Hjort has told us, I think you will be convinced that an advance has been made in the methods of deep-sea study. During the last ten years in the International Fisheries investigation, Dr. Hjort, amongst others, had made very great advances in the study of the economic fishes, that is to say, as to where they lay their eggs, where the larvæ are found, and what the rings on scales and ear-bones mean. The methods of taking temperatures, the water-bottles, current meters, and light investigations have all been improved. It was desirable to see how far these methods could be carried out in very deep water, down, say, to 3 miles. To do this in a little boat like the *Michael Sars*, of less than 250 tons burden, was in my opinion a very great feat. If we have been able to do so much in these four months, it is because these Norwegian sailors and scientific men had been accustomed to work in the deep sea, and the scientific staff did not require a month or two to get over sea-sickness. Work was commenced at once, and it was continued during the whole of the cruise. When the observations have been fully compared and discussed in the manner laid before us this evening, they will, I believe, show that an important advance has been made in our knowledge of the ocean and in the manner in which it may best be investigated. We shall, I am sure, have other similar expeditions in the near future.

Mr. J. Y. BUCHANAN: I must bear my testimony to the interest of the work which Dr. Hjort has brought before us; it will certainly go far to advance the study of the sea. I was particularly struck by the way in which he laid before us his material with regard to the distribution in depth of the animals, and illustrated it by such beautiful slides. The result is to show that the idea that life is scarce in intermediate depths cannot be maintained, and to support the opposite view which I formed on the basis of the deficiency of oxygen in the gases extracted from these waters. Dr. Hjort's observations of currents have interested me much. He has taken up and extended a branch of investigation in which I did a good deal of work, in 1883 in the *Dacia* and in 1886 in the *Buccaneer*. It was then shown that wherever the great tidal undulation which follows the sun and moon round the globe meets with a shoaling in its path, even at the greatest depths, the wave is to a certain extent broken, and, to that extent, converted into a current, which has the reciprocating motion of the tides. This current keeps the ridge clear of ooze, which then settles all the more abundantly in the sheltered parts. Such ridges as, for instance, the Faraday ridge in the North Atlantic, are very dangerous to submarine cables.

In the Straits of Gibraltar Dr. Hjort anchored his ship for twenty-four hours, during which he made many physical observations, especially regarding the motions of the water, for which purpose he used a new current meter. The currents in this passage have frequently engaged attention, both on account of their scientific and their nautical interest. A detailed investigation of them was made by Sir George Nares and Dr. Carpenter in H.M.S. *Shearwater* in the year 1871. From these investigations it appeared that there were usually two currents in the straits at the same time, one superposed on the other. Both were found to be affected by tidal influence, but after allowing for it there was a balance of inflow in the upper and of outflow in the under current. The balance of outflow over inflow at the bottom was well shown by the result of soundings as much as 200 miles north-west of the entrance of the straits, where, in a depth of 1560 fathoms, water of decided Mediterranean origin was got from the bottom. These currents and their influence in preventing the salting up of the Mediterranean are fully dealt with in the article "Mediterranean," which I contributed to the 'Encyclopædia Britannica,' 9th edition. It is too late now to add anything more. The whole lecture has been full of the greatest interest to all of us, and I can only thank Dr. Hjort for having brought it before us, Dr. W. E. HOYLE: What has appealed to me, I think, more especially are the observations regarding the colours of the deep-sea animals. It was known that a large number of deep-sea animals were deep red, but I do not think the cause of this has been adequately explained until this evening.

Dr. H. R. MILL: It is a very great pleasure to have Dr. Hjort with us once again, and to hear from him of all these admirable results which he and his Norwegian colleagues have obtained in the North Atlantic—obtained by the aid and support, not only financial, but moral and even physical, of Sir John Murray. Of the courage of Sir John in venturing himself on the great ocean in this little viking ship, we cannot speak too highly; but he never seems to grow old. When I heard him to-night describing the results with such keen interest, it recalled the first time I heard him speak in Edinburgh, when he was fresh from the *Challenger* expedition, now considerably more than thirty years ago. And I can assure you that the enthusiasm with which he described those entirely new results then was not a bit greater than that with which to-night he has described the still newer results that he obtained last year. If the Norwegians are proud of their expedition, as they ought to be, I think we also may be proud of having two such oceanographers as Sir John Murray and Mr. Buchanan, who, of all men in the world, might be expected to believe that the sum of oceanographical research was contained in the fifty huge volumes of the *Challenger* expedition; but who, instead of believing that an end has come to the acquisition of knowledge after that great expedition, are here as eager as ever to receive the fresh results of the present day; willing to recognize the new methods that have been introduced, and to allow that even if they will not permit the Atlantic to be called "an unknown sea," it at least forms as fine a field for investigation now as in the past. I consider that the results of the expedition of the *Michael Sars* are of a most stimulating character; I have rarely enjoyed a meeting of this Society more, and I wish to express my great thanks to Dr. Hjort and Sir John Murray for the treat they have given us. I am sorry that my friends Dr. Dickson and Dr. Fowler are not present, for they would appreciate many of the points better than any one else. Dr. Dickson has worked out the results that Dr. Wolfenden obtained in the *Silver Bell*, which confirmed the *Challenger* discovery as to the way in which the Mediterranean water warmed and salted the North Atlantic; and Dr. Fowler has worked out the movements of the small animals and plants of the water, known collectively as plankton, as they sway upwards and downwards according to the alternation of light and darkness—a piece of research which Dr. Hjort has extended in that most fascinating demonstration which shows how, as the penetration of light in the water varies according to latitude, the zones in which these animals live rise to the surface or fall away towards the depths of the ocean. I do not think I have ever heard anything more interesting in the way of geographical relationships than this union of mathematical with biological geography.

Mr. W. E. ARCHER: So much has already been said by previous speakers that I will do no more than express my personal appreciation of the very interesting lecture Dr. Hjort has given us. From my long association with Dr. Hjort in another series of investigations with regard to commercial fisheries, I felt sure his lecture would be full of interest, and I have not been disappointed.

The PRESIDENT: In connection with this lecture it may perhaps be asked, Who was Michael Sars? He was a biologist who many years ago did admirable work in Norway under great difficulties, living in a quiet Norwegian village, and working at deep-sea animals with no outside help whatever. When the Norwegian ship for oceanographic research came to be christened by our lecturer, he very appropriately gave it the name of ***Michael Sars***, a most suitable name, as being prophetic of the high reputation he himself would make in this class of scientific work. I may also add that the daughter of Michael Sars married the great Nansen, which is an interesting fact to remember in connection with this expedition. We have been looking at all questions to-night almost exclusively from a scientific point of view, and that no doubt is the right attitude for a man of science. But, though we should seek for knowledge for knowledge's sake, in nearly all these cases, when the search is pursued in this spirit, some practical good will come from it to the human race. Dr. Hjort does not hold out much hopes to us that any of these deep-sea fishes will afford a supply of human food, although the prawns taken from several hundred feet deep were excellent eating. But there are many other ways in which practical benefits may be reaped, of which only one will I mention. Some time ago my friend Mr. R. K. Gray raised the question in conversation with me whether those currents in mid-ocean, which are due to tides, may not so put a vessel out of its course as to be the cause of some of the many serious accidents to shipping so often occurring. If this investigation of ocean currents should add even in a very small degree to the safety of the ships of all nations, its cost will be covered a hundredfold. It is, however, as men of science that we must mainly congratulate Dr. Hjort and Sir John Murray for the admirable work they have done on the *Michael Sars.*

Dr. Hjort: May I thank you, Mr. President, for the very kind words you have said of me, and every one who has spoken, for their friendly remarks about my work? It has been a very great pleasure for me to have had this co-operation with British scientific men. My Norwegian companions and myself were from the very first, when we came here in the beginning of April last year, as cordially received as colleagues as any men could be. We were most cordially received by our friends in Plymouth, and by the scientific men here in London, and kindly again when we arrived in Glasgow; after the cruise the Norwegian members of the expedition are very thankful for all the great kindness which has been shown to us. I should like especially to be allowed to say one special word, to thank Sir John Murray. It is one of the greatest pleasures of my life that Sir John Murray had such great confidence in me as to ask me to undertake this expedition. I do not know any one whose esteem is dearer to me than Sir John Murray, not only because of his great work in the *Challenger* expedition, which has been the foundation of all oceanography, and has been our study since we were young students, but also because of his great personality. I remember once that Sir John Murray, when asked to give his title, said, "Well, I am a student." I think that this is the highest title, the greatest and most noble title, which a man, even Sir John Murray, can have, and I think nobody has deserved it more than he has, and I think, as my friend Dr. Mill has remarked, that his participation in our expedition is a new proof of his great and energetic interest for the advancement of oceanography.

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Johan Hjort, Die Tiefsee-Expedition des „Michael Sars" nach dem Nordatlantik im Sommer 1910. Mit Tafel XI und 15 Textfiguren 152

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B. Berichte, Länderreferate und Einzelreferate.

Die Tiefsee-Expedition des „Michael Sars“ nach dem Nordatlantik im Sommer 1910.[1])

Von

Dr. **Johan Hjort** (Bergen).

Erster Teil mit Tafel XI und 12 Textfiguren.

Inhalt: Einleitung. — I. Hydrographische Untersuchungen. — II. Phytoplankton.

Im August 1909 schrieb Sir John Murray an mich und erbot sich, die Kosten einer Expedition nach dem Nordatlantik mit dem norwegischen Untersuchungsdampfer „Michael Sars“ zu tragen. Seit 1900 habe ich mit meinen Assistenten auf diesem Dampfer Fahrten in den norwegischen Meeren unternommen. Wir versuchten, die Verteilung der Meeresströmungen, ebenso ihre Bewegungen und Schwankungen festzustellen, und wir machten auch eine Anzahl Beobachtungen hinsichtlich der Lebensgeschichte von Fischen und anderen Organismen. Wir hatten oft Gelegenheit gehabt, den Einfluß des Atlantischen Ozeans auf die nördlicheren Gewässer zu bemerken. Wir hatten gesehen, wie die in die Norwegische- und Nord-See einströmende, veränderliche Menge von Wasser aus dem Atlantik die hydrographischen Bedingungen in jenen Meeren beeinflussen und bestimmen kann. Außerdem hatten wir die Tatsache feststellen können, daß jährlich eine große Einwanderung atlantischer Organismen in die nordeuropäischen Küstengewässer stattfindet.

Nur einmal vorher hatte ich Gelegenheit gehabt, den Atlantischen Ozean kurz zu befahren. Dabei war es uns gelungen, bei einem einzigen Zuge mit dem Schleppnetz aus einer Tiefe von 500 Faden unter einer größeren Anzahl Fischen nicht weniger als 100 Exemplare zu fangen, die neuen Spezies angehörten. Seitdem hatte ich oft gewünscht, die Wasser des Atlantiks zu untersuchen, so daß Sir John Murrays großmütiges Anerbieten mir eine willkommene Überraschung war.

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[1]) Anm. der Red. Nach einem Vortrag vor der „Royal Geograph. Society in London“. Dieser Aufsatz erscheint gleichzeitig im „Geograph. Journal“ (April- und Mai-Nummer) in englischer Sprache.

3. Während der hellen Stunden (6 Uhr morgens bis 6 Uhr abends) findet sich die größte Ansammlung wahrscheinlich in ca. 360 m Tiefe (Tabelle 6).

4. In 180 m Tiefe fängt man am frühen Morgen und Abend ungefähr gleich viel (Tabelle 4, D, 2—3), aber in 360 m beträgt abends der durchschnittliche Fang pro Stunde nur wenig mehr als die Hälfte eines entsprechenden Fanges am Tage (Tabelle 4, F). Ein großer Teil der Population scheint also abends aus dieser Zone nach oben gewandert zu sein. Alle Schichten oberhalb 36 m sind tagsüber ärmer an Individuen, als zu jeder anderen Stunde (Tabelle 5).

5. Die Wanderungen werden wahrscheinlich durch Lichtwirkung verursacht; doch scheint eine bestimmt gerichtete Bewegung — nach einer schwächeren Lichtintensität hin oder von einer stärkeren weg — der Erscheinung nicht zugrunde zu liegen. Vielmehr dürfte der Einfluß des Lichtes auf den Geotropismus der Tiere die hauptsächliche Ursache sein.

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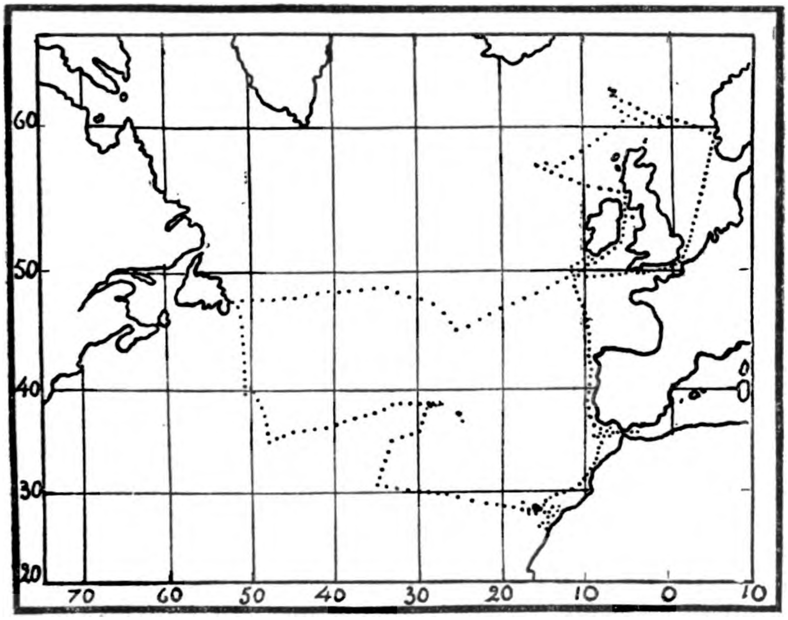
Die norwegische Regierung war unserem Unternehmen sehr gewogen und stellte uns das Schiff vollständig zur Verfügung und meine Kollegen, die sich schon so lange an diesen Untersuchungen beteiligt hatten: Professor H. H. Gran, Dr. Helland-Hansen, Herr E. Koefoed und Kapitän Thor Iversen, drückten sämtlich ihre größte Bereitwilligkeit aus, sich der Expedition anzuschließen.

Nach Vollendung unserer Vorbereitungen fuhren wir von Plymouth, wo sich Sir John Murray der Expedition anschloß, Anfang April 1910 ab. Zunächst fischten wir mit dem Trawl westlich von Irland, über dem Abfall der Küstenbänke, und machten dort hydrographische Untersuchungen. Dann fuhren wir quer über den Golf von Biscaya, wo wir eine Anzahl Untersuchungen anstellten, nach der Nordwestecke von Spanien. Von dort aus folgten wir der spanischen und portugiesischen Küste bis hinab nach Gibraltar. In der Meerenge erhielten wir eine Serie von Strömungsmessungen. Danach wurde die Bai von Cadix untersucht. Wir machten sorgfältige hydrographische Beobachtungen über die Meeresströmungen in verschiedenen Teilen dieser interessanten Gewässer. Zur selben Zeit wurde eine Reihe von Trawlzügen von der Küste an bis hinab zu großen Tiefen ausgeführt.



Route der „Michael Sars"-Expedition.

Dann dampften wir in der Richtung der Kanarischen Inseln weiter und untersuchten den Westabhang Afrikas von der Küste bis zum Grunde des Meeres. Darauf begann ein langes Kreuzen durch den Atlantik, wobei wir die Azoren, das Sargassomeer und gelegentlich auch Neu-Fundland besuchten.

Während der ganzen Dauer dieser Fahrt, die 40 Stationen umfaßt, machten wir beständig hydrographische Untersuchungen und gebrauchten die verschiedensten Instrumente, um planktonische Organismen von allen Größen zu sammeln. Eine gleiche Durchquerung wurde im Juli unternommen zwischen Neu-Fundland und Irland (22 Stationen), und wir brachten unsere Nachforschungen zum Abschluß, indem wir die Gewässer zwischen Glasgow, Rockall, den Färoer- und Shetland-Inseln, d. h. die Gewässer südlich und nördlich des Wyville Thomsonrückens, einer genaueren Prüfung unterzogen, um den Übergang vom Atlantik in das norwegische Meer zu studieren.

Während der 4 Monate unserer Fahrt ist sehr viel geleistet worden. Und es muß die Ozeonographen interessieren zu hören, daß ein kleiner Dampfer von nur 226 t, so viele und so verschiedenartige Untersuchungen in einem der großen Ozeane ausführen konnte. Ich will deshalb zur Illustrierung des Geleisteten ein paar Zahlen anführen.

An hydrographischem Material sammelten wir 2400 Wasserproben, von denen mehr als 900 aus größerer oder geringerer Tiefe stammen. An 110 Stationen machten wir 937 Temperaturbeobachtungen unterhalb der Oberfläche, während 1625 Oberflächentemperaturmessungen während der Fahrt notiert wurden. Dazu maßen wir 258 mal Strömungen und versuchten 7 mal festzustellen, wie weit das Licht durch die Oberflächenschichten eindränge. Um das pflanzliche Plankton zu studieren, machten wir 140 Vertikalfänge und nahmen 38 Wasserproben zum Filtrieren und 58 Proben für die Zentrifuge. Um das größere Plankton zu erhalten, machten wir 95 Vertikalfänge mit Netzen von verschiedener Größe, 193 Horizontalfänge mit Seidennetzen, 80 Horizontalfänge mit pelagischen Netzen und 18 Fänge mit einem sehr großen Schleppnetz. Dretschzüge wurden an 24 Orten in verschiedenen Tiefen ausgeführt.

Daraus, daß wir imstande waren, so viele Untersuchungen auszuführen, trotzdem das Schiff während der Fahrtdauer von 4 Monaten ungefähr 11 000 Meilen zurücklegte, geht hervor, daß ozeanographische Expeditionen mit kleinen Fahrzeugen und verhältnismäßig geringen Kosten unternommen werden können. Und das wird man bei der Ausrüstung neuer Expeditionen wohl in Betracht ziehen.

Wir kehrten von unserer Fahrt am 15. August zurück. Und in den seither verflossenen 5 Monaten haben wir soviel wie möglich von der großen Menge des gesammelten Materials untersucht. Dr. Helland-Hansen hat das hydrographische Material übernommen, Professor Gran das Phytoplankton, und ich selbst habe die Bearbeitung des zoologischen Materials in die Wege geleitet. Aber es ist klar, daß wir jetzt nur einen Bruchteil des Ganzen haben in Angriff nehmen können.

Ich würde gern der Aufforderung der kgl. geographischen Gesellschaft nachkommen und über die Resultate unserer Expedition Bericht erstatten. Aber leider bin ich vorläufig nicht imstande, mehr als ein paar der Erfahrungen anzuführen, die wir durch unsere Arbeitsweise gewonnen haben, und die Ideen auseinanderzusetzen, die uns bei unsereren Bemühungen leiteten. Vor allem wird es mein Ziel sein, die Probleme herauszustellen, die sich uns während unserer Arbeit aufdrängten, und die einer künftigen Lösung harren. Weder meine Kollegen noch ich selbst haben uns dem Eindruck entziehen können, ein wie reiches Feld für weitere Untersuchungen der Nordatlantik darstellt. Und ich hoffe, daß die Beiträge zu unserer Kenntnis jenes Ozeans, die ich jetzt, dank der Unterstützung seitens meiner Mitarbeiter vorlegen kann, helfen werden, Interesse für künftige Untersuchungen in jenen Gegenden zu erwecken.

I. Hydrographische Untersuchungen.

An 110 Stationen sammelten wir Material zur Bestimmung der Temperatur und des Salzgehaltes des Seewassers. Die Temperaturbeobachtungen sind jetzt genau durchgesehen, die Wasserproben titriert, und die Resultate sind in Profilen und Karten niedergelegt worden, die die Verteilung des Salzgehaltes und die Temperatur in den verschiedenen Tiefen zeigen. Ich werde jetzt ein paar Beispiele unserer Ergebnisse anführen.[1])

Fig. 1 zeigt die Verteilung des Salzgehaltes und der Temperatur in dem Teil des Meeres zwischen Neufundland und Irland im Juli 1910. Beinahe durch den ganzen Querschnitt erstreckt sich in den obersten 150—200 m eine Schicht mit einem Salzgehalte von $35{,}5\,^{0}/_{0}$. Sowohl Salzgehalt wie Temperatur nehmen nach der Tiefe zu ziemlich regelmäßig ab, bis wir eine gleichförmige Schicht, das „Bodenwasser" erreichen, wo die Temperatur kaum unter 2,5° C sinkt, während der Salzgehalt ungefähr 34,9 pro mille beträgt. Es ist bemerkenswert, daß dieser Salzgehalt genau dem entspricht, den man während früherer Untersuchungen in dem Bodenwasser des norwegischen Meeres gefunden hat. Während der Fahrt des „Michael Sars" im Atlantik ist derselbe Salzgehalt festgestellt worden zwischen den Kanaren und den Azoren, zwischen den Azoren und Neufundland, außerdem außerhalb des Golfes von Biscaya.

Diese gleichförmige Bodenwasserschicht befindet sich im östlichen Teile des Nordatlantik, an der Südküste Europas und der Nordküste Afrikas, in größerer Tiefe als im westlichen Teil, an der amerikanischen Küste. Östlich von Neufundland steigt diese Schicht verhältnismäßig stark an, wie aus der Karte in Fig. 2 hervorgeht, die die Verhältnisse in einer Tiefe von 500 Faden darstellt. Daraus scheint hervorzugehen, daß das Bodenwasser des Nordatlantiks aus dem nordwestlichen Teile dieses Ozeans kommt.

Die Karte zeigt deutlich den Einfluß auf das Mittelländische Meer, der zuerst durch Dr. J. J. Buchanan und kürzlich von N. J. Nielsen von der dänischen Meeresuntersuchung studiert worden ist. Sehr salziges und verhältnismäßig warmes Wasser strömt aus dem Mittelländischen Meer hinaus und sinkt

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[1]) Die Temperaturen sind in der Hauptsache mittels des Richterschen Kippthermometers festgestellt worden. In 517 Fällen benutzten wir dieselben beiden Thermometer gleichzeitig. Der Unterschied zwischen den korrigierten Werten beider betrug im Durchschnitt 0,01° C. Dr. Helland-Hansen meint, daß unsere Temperaturbestimmungen auf ein paar hundertstel Grad genau seien. Die Wasserproben wurden größtenteils mit Ekmans Kippwasserschöpfer gesammelt. Der Salzgehalt wurde durch Chlortitrationen festgestellt. Alle Proben wurden zweimal titriert und wir glauben, daß die Salzgehaltsbestimmungen bis auf ungefähr $^{1}/_{100000}$ genau sind. Wir machten unsere Beobachtungen meistens an der Oberfläche in folgenden Tiefen: bei 25, 50, 75, 100, 150, 200, 250, 300, 350, 600, 800 und 1000 Faden. Es gibt nur verhältnismäßig wenig Beobachtungen aus größerer Tiefe.

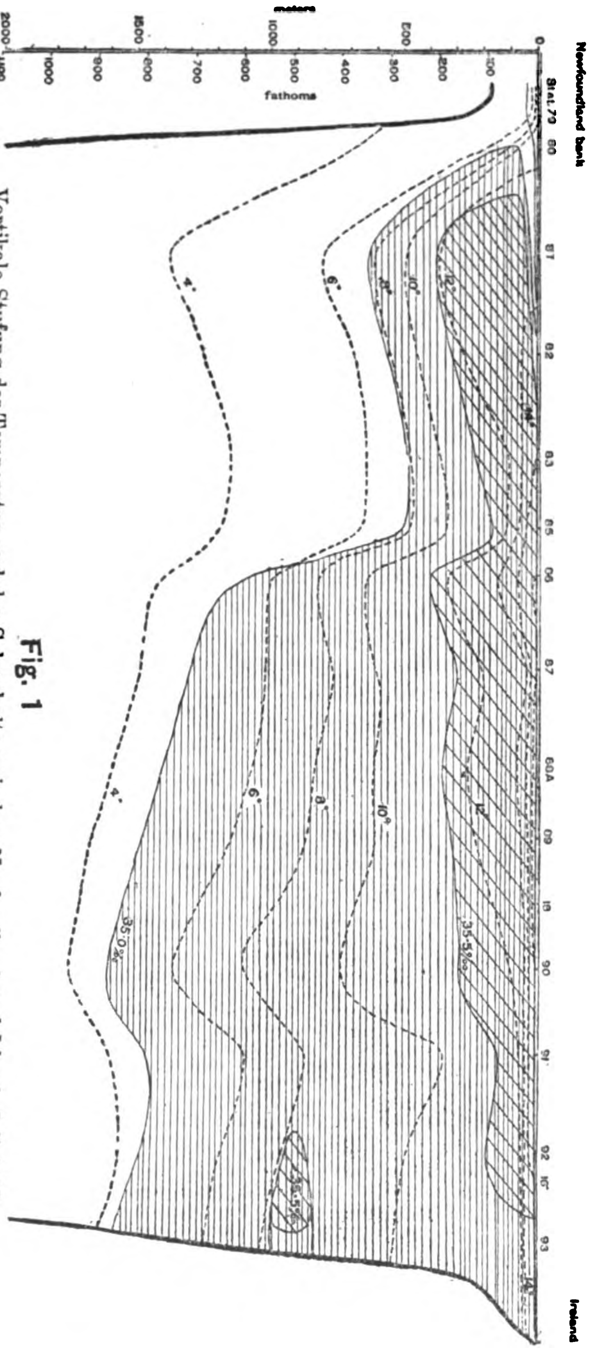

Fig. 1

Vertikale Stufung der Temperatur und des Salzgehalts zwischen Neufundland und Irland, Juli 1910.

in die tieferen Schichten; jenseits von Spanien fließt die Hauptmasse infolge der Erdrotation nach Norden, während ein Teil der gewöhnlichen Strömung nach Südosten folgt. Zwischen dem ziemlich salzarmen, kalten Wasser im Nordwesten und dem verhältnismäßig warmen salzreichen Wasser in der Nähe von Spanien erstreckt sich von den westlichen Azoren bis hinauf zu den Färoer und Island ein Gürtel mit einem ziemlich gleichmäßigen Salzgehalt von 35—35,5 pro mille und einer Temperatur von 6—8° C.

In Fig. 1, bei Station 81 und 82 sehen wir eine ziemlich große Masse von salzigen, warmen Wasser. Weiter östlich, bei Station 85, nimmt sie beträchtlich ab.

Fig. 3 stellt einen Schnitt vom Sargassomeer bis Neufundland dar; dieser zeigt noch auffallendere Unterschiede. Die Verhältnisse bei Station 66 sind außerordentlich bemerkenswert. Das sehr salzige warme Wasser des Sargassomeeres und seiner Umgebung wurde durch eine Art Kaltwasserkeil von einer gleichen, warmen Salzwasserschicht in der Nähe von Amerika getrennt. Die Karte in Fig. 4 zeigt die Verhältnisse in einer Tiefe von 200 Faden. Indessen ist es zweifeläußerst wichtig ist. Wenn die Karte korrekt ist, dann muß auch ein nach Südwesten fließender Gegenstrom vorhanden gewesen sein, der die nach Norden sich ergießenden Wassermassen teilte. Durch eine große Anzahl von

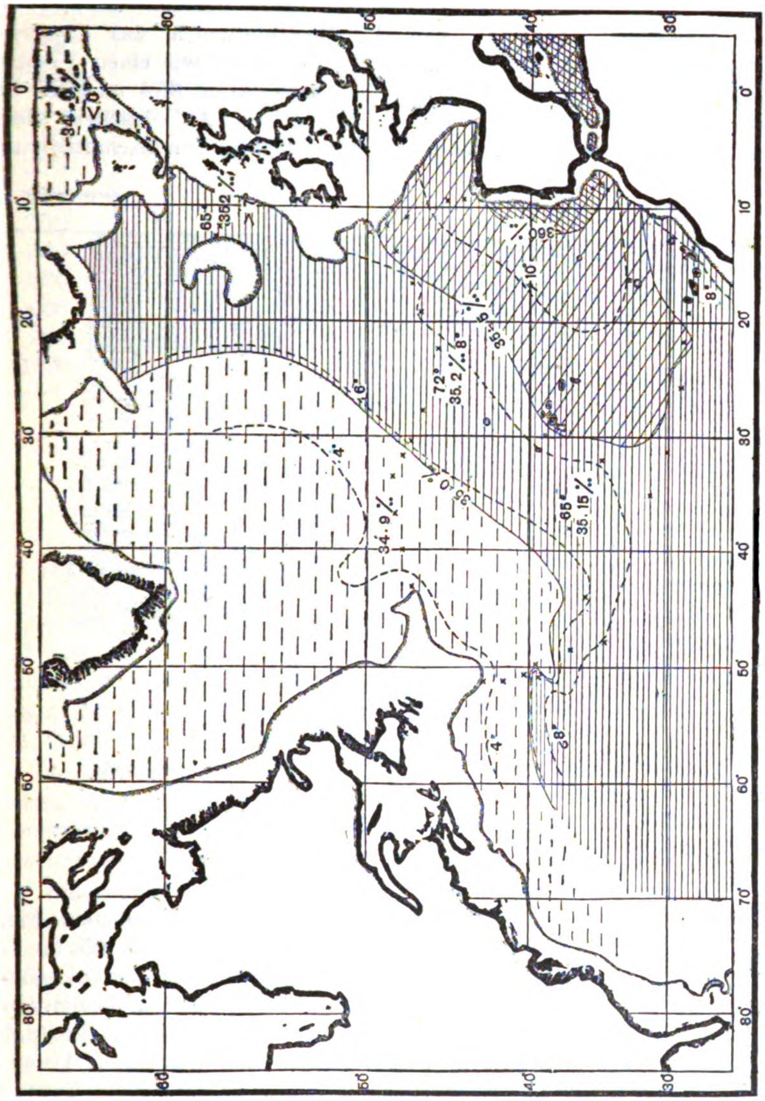

Fig. 2

Verteilung von Temperatur und Salzgehalt in einer Tiefe von 900 m (500 Faden).

haft, ob wirklich eine solch große Verschiedenheit der Strömung existiert, wie die Kurven anzudeuten scheinen. Nur durch fernere und eingehendere Untersuchungen kann diese Frage gelöst werden, die für das ganze Verständnis des Systems von Strömungen in diesen Gewässern Beobachtungen hätte es sich vielleicht gezeigt, daß wir die Kurven anders hätten zeichnen sollen; oder vielleicht waren die Verhältnisse nur gerade so zurzeit, da wir unsere Untersuchungen ausführten.

Wenn wir unsere Temperaturbeobachtungen mit denen des Challenger vergleichen, so finden wir erfreulicherweise eine große Übereinstimmung, was die tieferen Schichten angeht — und die Beobachtungen des Challenger scheinen sehr genau gewesen zu sein. In Fig. 5 haben wir einen Vergleich zwischen der Temperaturverteilung an der Challengerstation 354 im Mai 1876 und an der Michael Sars-Station 61 im Juni 1910. An einzelnen kleinen Punkten gehen sie auseinander, aber die (punktierten) Durchschnittskurven des Challenger fallen ziemlich mit denen des Michael Sars zusammen. Fig. 6 zeigt einen ebensolchen Vergleich zwischen der Challengerstation 65 im Juni 1873 und der Michael Sars-Station 65 im Juni 1910. Hier sind die Unterschiede auffallend groß, sie betragen sogar mehr als 3° C in den mittleren Wasserschichten. Das kann nicht einem Fehler in der Methode zugeschrieben werden. Denn erstens stimmen die Temperaturen in den größeren Tiefen in beiden Beobachtungsreihen zufriedenstellend überein, und zweitens liegen die Stationen in einem Gebiete, aus dem keine schnellen Veränderungen bekannt sind. Wenn wir die Stationen des Challenger aus dem Sommer 1873 mit den benachbarten des Michael Sars aus dem Sommer 1910, also 37 Jahre später, vergleichen, so finden wir durchweg, daß das Wasser der mittleren Schichten 1873 viel wärmer war als 1910.

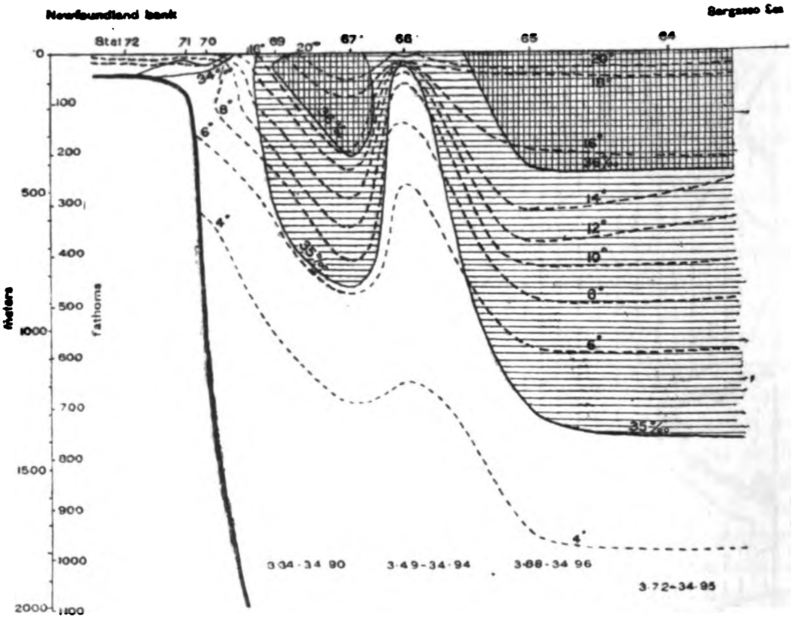

Fig. 3

Schnitt vom Sargassomeer bis Neufundland.

Temperatur des Atlantik.
Juni 1873 (Challenger) und Juni 1910 (Michael Sars).
Temperaturunterschiede (° C).

Tiefe in Fäden	A. zwischen Challenger, Stat. 65 und Michael Sars, Stat. 65	B. Ch., Stat. 66 M. S., Stat. 63	C. Ch., Stat. 69 M. S., Stat. 60
0	0,6°	+1.2°	2,3°
100	1,1°	0,5°	0.8°
200	1,7°	1,2°	1,6°
300	2,2°	3,7°	2,8°
400	3,2°	4,8°	2,8°
500	3,2°	4,3°	2,0°
600	1,9°	1,9°	0,7°
800	0,7°	—	—
1000	0,1°	—	0,4°
	Ch. 65, 36° 33′ N. 47° 58′ W. M. S. 65, 37° 12′ N. 48° 30′ W.	Ch. 66, 37° 24′ N. 44° 14′ W. M. S. 63, 36° 5′ N. 43° 58′ W.	Ch. 69, 38° 23′ N. 37° 31′ W. M. S. 60, 41° 39′ N. 51° 4′ W.

Die Tabelle zeigt die Temperaturunterschiede (in ° C) zwischen einer der Challenger- und einer der Michael Sars-Stationen. Der Unterschied beträgt in den mittleren Wasserschichten bis zu 5°, sinkt dagegen in der Tiefe auf 0,1° resp. 0,4°. Dies scheint anzudeuten, daß in den mittleren Wasserschichten von einem Jahr zum anderen so große Wärmeschwankungen stattfinden, daß diese sogar die periodischen Schwankungen übertreffen, die aus dem Wechsel der Jahreszeiten resultieren.

Es ist augenscheinlich, daß Wärmeschwankungen dieser Art im Atlantischen Ozean äußerst wichtig sind und weiterer Aufklärung bedürfen. Im Norwegischen Meere sind solche Schwankungen schon früher durch Michael Sars in dem aus dem Atlantik hereinströmenden Wasser nachgewiesen worden.

Diese Bestimmungen der Temperatur und des Salzgehaltes von Meerwasser werden künftig für dynamische Berechnungen benutzt werden. Dadurch wird es möglich sein, Schlüsse auf die Bewegung der verschiedenen Wasserschichten zu machen. Die Expedition versuchte auch, diese Bewegungen direkt festzustellen mittels des von Ekman konstruierten Propellerstrommessers.[1])

In der Straße von Gibraltar versuchten wir zunächst, eines der Rettungsboote vorn und hinten zu verankern, wie wir früher oft im Norwegischen Meere getan hatten. Indessen wurden durch die starke Strömung die Taue wiederholt zerrissen. Darum verankerten wir das Schiff selbst in 200 Faden

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[1]) Bei Bearbeitung dieser Resultate ist Dr. Helland-Hansen von Dr. Hanzlik in Prag unterstützt worden.

Tiefe, mit $1^1/_2$ Zoll starken Stahltrossen und einem Wurfanker. So lag das Schiff am 30. April von $2^1/_2$ Uhr p. m. Während dieser Zeit stellten wir 70 Messungen in 8 verschiedenen Tiefen an.

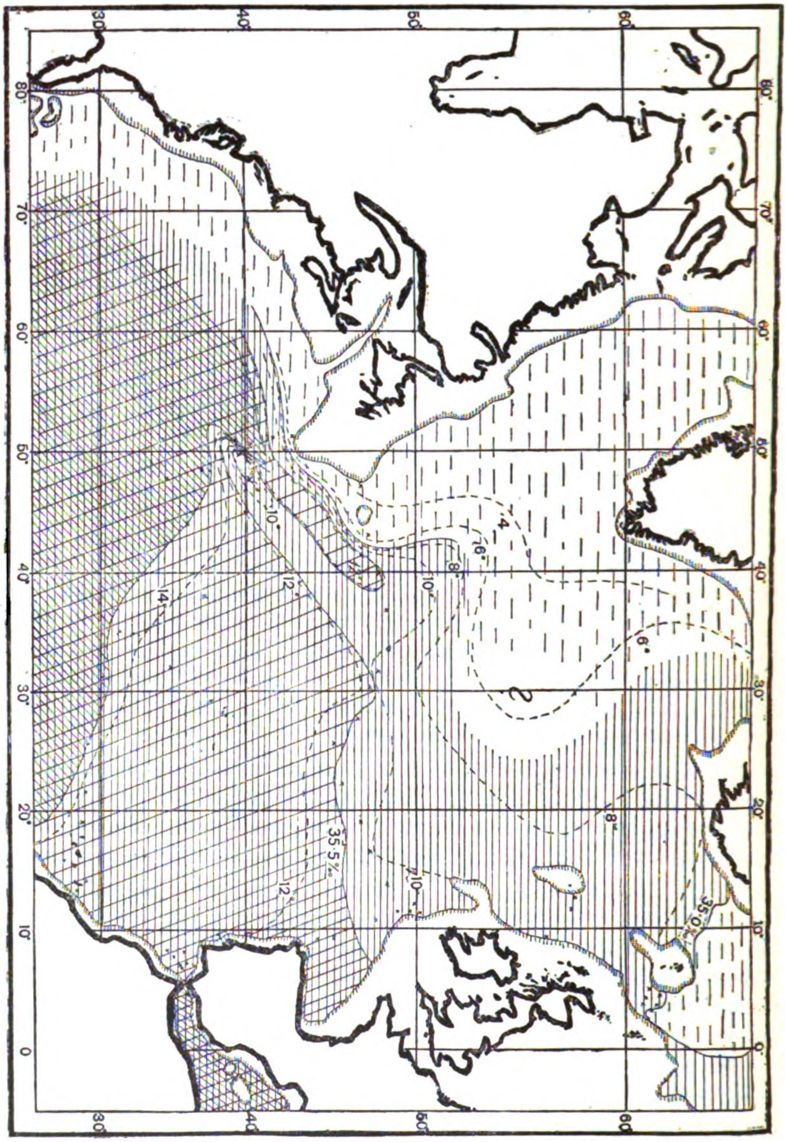

Fig. 4

Temperatur und Salzgehalt in 380 m Tiefe 200 Faden).

Fig. 7 und 8 zeigt die Resultate dieser Messungen, die für die Richtung entlang der Mittellinie der Meerenge berechnet sind. Die Wasserschichten, die ins Mittelländische Meer hineinfließen, sind mit schrägen Linien, die in den

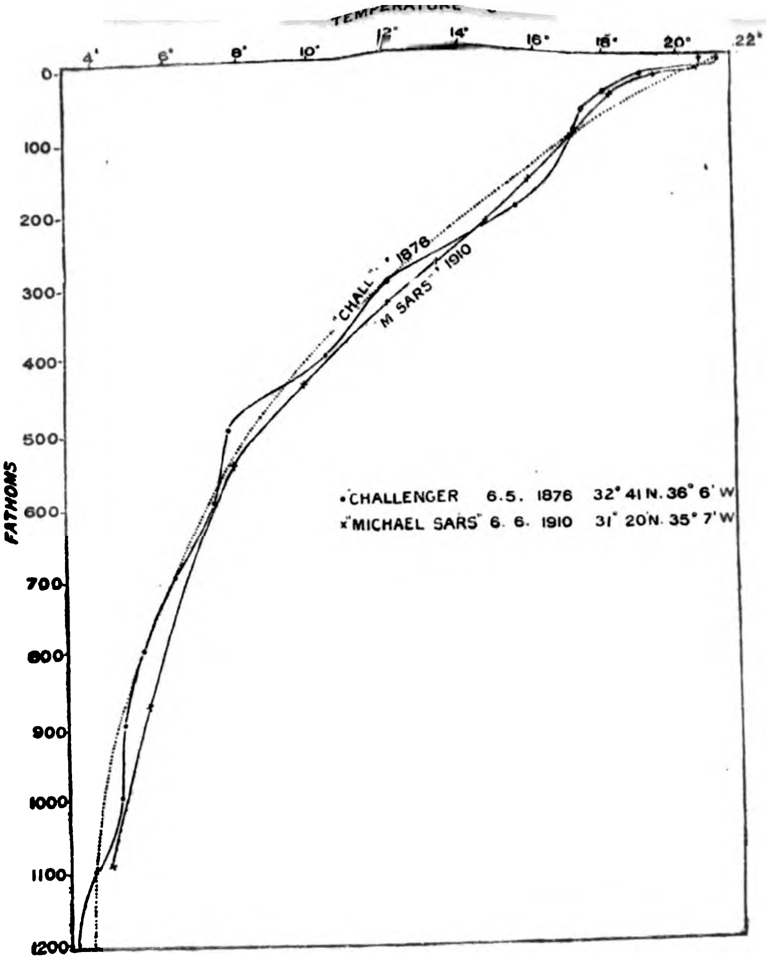

Fig. 5

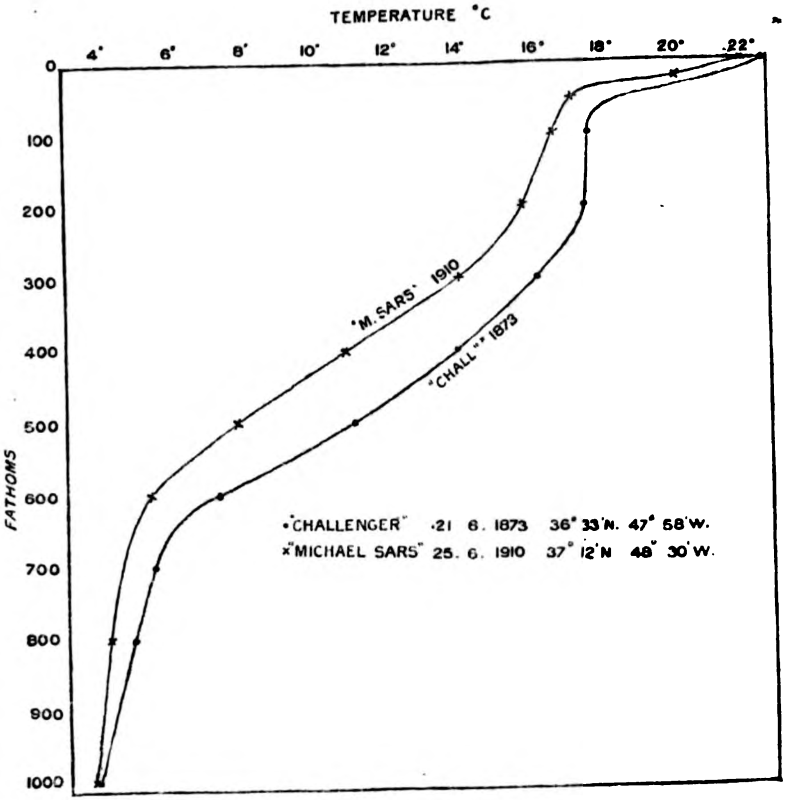

Fig. 6

Temperaturstufung nach den Befunden der Challenger- und Michael Sars-Expedition.

Atlantik hinausfließenden mit unterbrochenen Linien gezeichnet. Fig. 7 zeigt die Verhältnisse um 9 Uhr a. m., wo das Hineinströmen ins Mittelländische Meer am stärksten war. Fig. 8 gibt das Mittel der Messungen von 2 Uhr morgens und 3 Uhr nachmittags. Ein Vergleich der beiden Figuren zeigt, daß die Wirkungen der Flut auf die ganze Wassermasse, von der Oberfläche bis zum Grunde, sehr groß sind. Die horizontale Skala gibt die Geschwindigkeiten in Sekundenzentimetern an. Während des Hineinströmens (Fig. 7) betrug die Geschwindigkeit in der oberen einfließenden Schicht ungefähr 1 m pro Sek., dagegen in der tieferen, westwärts fließenden Schicht höchstens $^1/_3$ m. Während des Herausströmens aus dem Mittelländischen Meere in den Atlantik war eine Oberflächenströmung kaum festzustellen, während die Geschwindigkeit des herausströmenden Wassers in größerer Tiefe (300 m) bis zu 2 m pro Sek. anstieg. Die Geschwindigkeiten waren in Wirklichkeit noch größer, da die Strömung gewöhnlich in einer, zur Mittellinie der Meerenge leicht geneigten Richtung verlief.

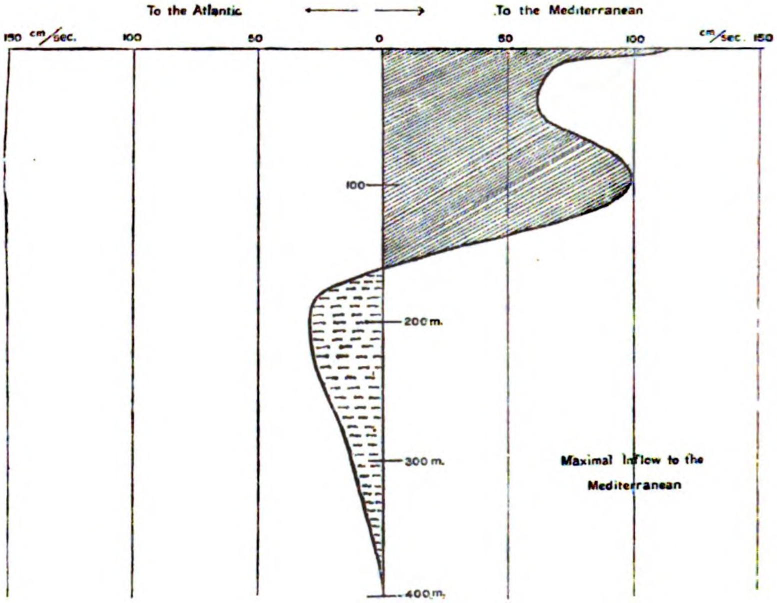

Fig. 7

Wasserbewegung in verschiedenen Tiefen der Straße von Gibraltar.

Während unserer Versuche mit dem großen Otter Trawl auf der Bank südlich von den Azoren, am 12. Juni, blieb das Trawl am Grunde festhängen. Statt es unmittelbar klarzumachen, benutzten wir diesen an sich unglücklichen Zufall, um Strommessungen anzustellen. Das Schiff war an dem Taue in einer Tiefe von 524 Faden (958 m) verankert. Im ganzen machten wir 90 Messungen in verschiedenen Tiefen, bis hinunter zu 800 m.

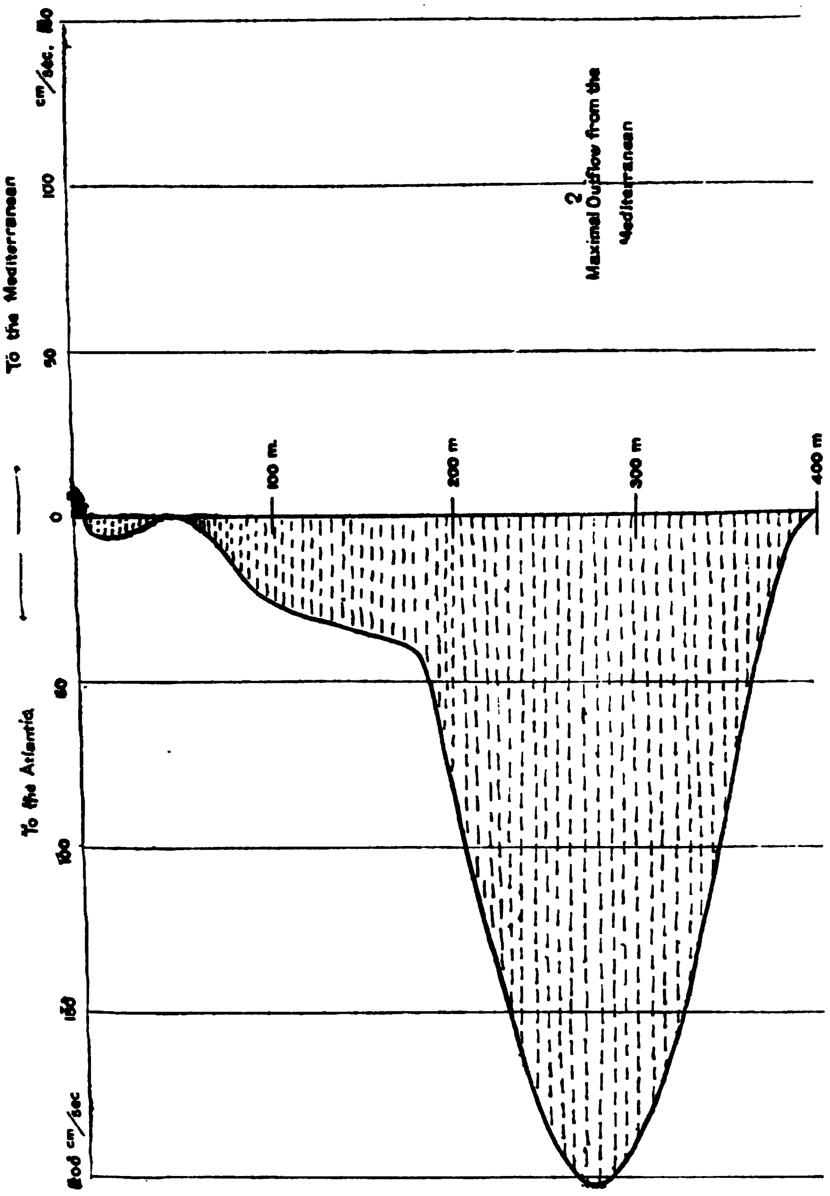

Fig. 8

Wasserbewegung in verschiedenen Tiefen der Straße von Gibraltar.

Fig. 9 zeigt Stunde für Stunde die Strömung in 10 m Tiefe. Deutlich kann man die Flutbewegungen erkennen. Der wirkliche Hauptstrom verlief südlich mit einer Geschwindigkeit von 8—9 cm pro Sekunde.

In Fig. 10 sehen wir die Strömungen in den verschiedenen Schichten in drei Zeitabschnitten: 1. um $3^1/_2$h. a.m., 2. um 7h. a.m., 3. um 10,45h. a.m.

Wenn man die drei Tabellen vergleicht, findet man, daß in allen Tiefen bi zu 800 m hinunter Flutbewegungen stattfanden; die Pfeile deuten alle nach rechts, von 1 durch 2 nach 3. Im allgemeinen waren die Strömungen de unteren Schichten denen der oberen entgegengesetzt. In 8 m Tiefe war um 3,30h a. m. eine starke Strömung; aber sonst fanden wir in der Regel, daß die Strömung nahe der Oberfläche am stärksten war, während bei 100 m die Geschwindigkeit sich verringerte und bei 200 m wieder zunahm.

Die Messungen ergaben in übereinstimmender Weise, daß sehr beträchtliche Flutströmungen sogar in 800 m Tiefe stattfinden können. Der Grund dafür, daß sie südlich der Azoren so stark sind, liegt wahrscheinlich zum großen Teil darin, daß hier eine bedeutende Untiefe ist, an der sich das Wasser staut.

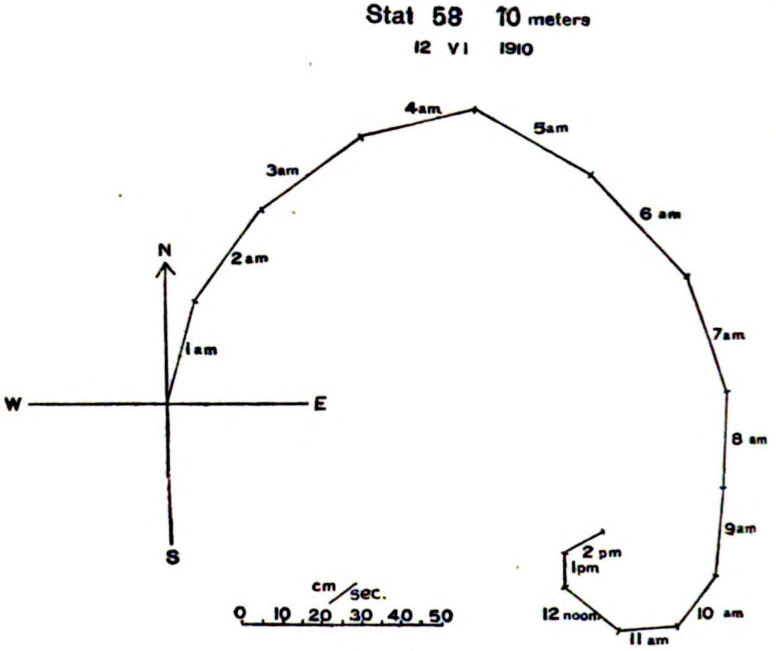

Fig. 9

Stromänderung in 10 m Tiefe von Stunde zu Stunde gemessen.

Gleiche Untersuchungen mit modernen Methoden sind vor den unseren noch nicht unternommen worden, weder in der Tiefe des Ozeans noch in der Straße von Gibraltar.

Daß Flutbewegungen auf hoher See und Strömungen bis zu einer Tiefe von über 400 Faden (800 m) existieren, ist aus mehr als einem Grunde interessant: denn diese Kenntnis erleichtert uns das Verständnis der Meeresströmungen, der Flutwelle, der Verbreitung der Organismen und der Verteilung der Ablagerungen am Meeresboden.

Es ist lange ein Rätsel gewesen, warum man in großen Meerestiefen Steine trifft, die nicht von Ablagerungen bedeckt sind, obgleich sie unzweifelhaft schon sehr lange dort gelegen haben. An den Abhängen der Küstenbänke südwestlich von Irland ließen wir unser Trawl bis zu 1000 Faden (1797 m) hinab und brachten unter anderem eine große Anzahl Steine mit herauf.

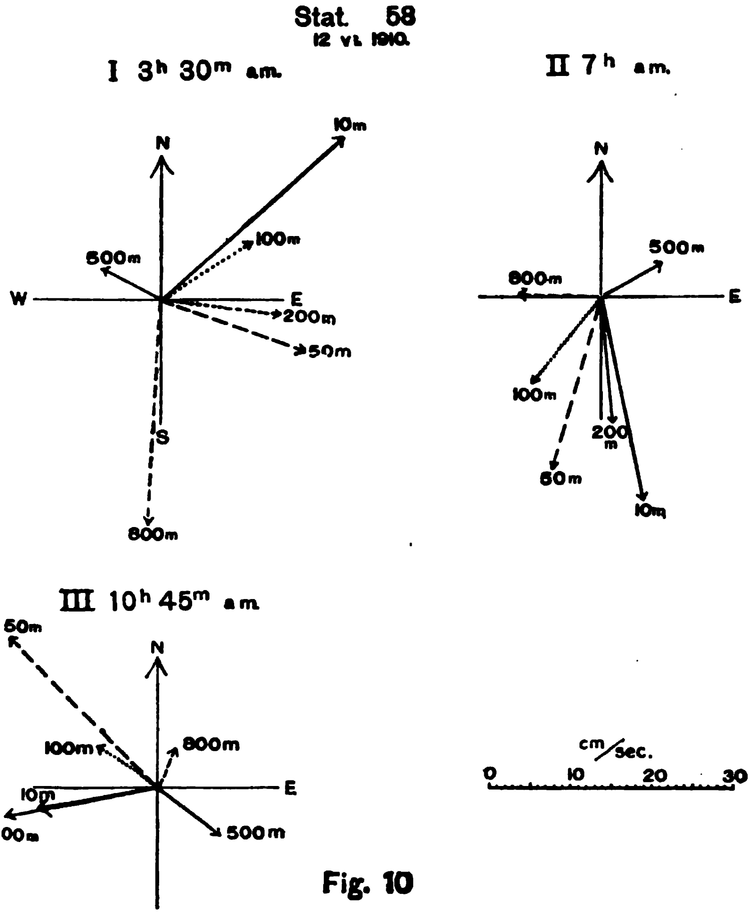

Fig. 10

Die Stromrichtung und Geschwindigkeit in verschiedenen Tiefen, zu drei verschiedenen Tageszeiten gemessen.

Sir John Murray ließ die Steine durch Dr. Peach untersuchen. Wie Sir John Murray in seinem Vortrag vor der Royal Scottish Geographical Society in Edinburgh am 11. November 1910 erwähnt, berichtet Dr. Peach „daß ganze 20 Prozent dieser Steine aus der Eiszeit stammen. Sie bestehen aus Granit, Gneiß, Schiefer, Sandstein, Kalk, Kreide und Feuerstein. Der Zustand dieser Trümmergesteine läßt erkennen, daß sie vielfach über die Sedimentschicht, in die sie eingebettet waren, hervorragten. Dr. Peach zweifelt nicht, daß diese Steine während der späteren Eiszeitperioden durch das Eis an die Stelle geschafft worden sind, wo wir sie gefunden haben. Sie gehören fast alle den sedimentären, metamorphisierten und eruptiven Gesteinen an, die wir jetzt in diesem Lande und in Irland anstehend finden. Aber nun erhebt sich die interessante Frage, warum diese Trümmer nicht vollständig durch die beständig von der Oberfläche herabfallenden Schalen bedeckt worden sind. Nach Berichten von Telegrapheningenieuren muß man annehmen, daß an einigen Orten in gewissen Tiefen die Anhäufung mindestens einen Zoll aller zehn Jahre beträgt. Bei dieser Geschwindigkeit müßten die Gesteinstrümmer, die während der Eiszeit abgelagert wurden, längst so im Schlamm begraben sein, daß unser Trawl sie unmöglich hätte erreichen können. Höchstwahrscheinlich erstrecken sich nun die Flutbewegungen, deren Existenz wir in der Tiefe nachgewiesen haben, bis zum Grunde hinunter und entfernen die kleinen Globigerinenschalen von allen Vorsprüngen. Es mag aber auch eine andere Erklärung dafür geben"[1]).

II. Phytoplankton.

Während der ganzen Reise des Challenger wurden die planktonischen Formen, die man mit dem Schleppnetz fing, bestimmt, wie in der Übersicht der Resultate veröffentlicht ist. Und Sir John Murray machte einen ersten Versuch, zu bestimmen, welche Menge von Calcium-Carbonat, das in der Form von Schalen und Skeletten von den planktonischen Organismen ausgeschieden wird, in einem Volumen Meerwasser von einer Quadratmeile Oberfläche und 100 Faden Tiefe zu finden ist. Die genaue Untersuchung des Phytoplanktons des Nordatlantiks, mit Angabe der Individuenzahl der verschiedenen Spezies, wurde zuerst während Hensens Expedition 1889 vorgenommen, deren Ergebnisse nebenbei noch nicht alle veröffentlicht sind. Dann ist unsere Kenntnis erweitert worden durch die ausgedehnten Untersuchungen von Cleve, und die wertvollen Beiträge von J. Murray, Whitting und Blackman. Die Valdivia-Expedition stellte ihre Hauptforschungen im antarktischen und Indischen Ozean an, während sie im Atlantik verhältnismäßig wenig Untersuchungen ausführte. Was die Verteilung der Arten im Atlantik anbetrifft, so ist unsere Kenntnis, trotz der oben angeführten Arbeiten, noch ziemlich unvollständig.

Die Fänge, die wir mit dem Schleppnetz auf hoher See machten, können sich in keiner Weise mit denen vergleichen, die man in den norwegischen Küstengewässern erhalten kann. Die einzigen Ausnahmen bilden Fänge westlich von Irland und im Golf von Biscaya im April (Station 2, 3, 4, 7, 9, 10). Dort trafen wir auf große Mengen von Diatomeen, selbst bis hinunter in eine Tiefe von über 100 m.

Die ozeanischen Fänge sind dagegen sehr reich an Arten: in der Regel erhält man bei einem einzigen Fange von den oberen Schichten bis zu 100 m Tiefe mindestens 50. Viele Arten kommen so selten vor, daß es uns nur gelungen ist, ein paar Exemplare davon zu erbeuten. Aber die meisten sind trotz ihrer geringen Anzahl in den wärmeren Gewässern weit verbreitet, sind auch im Indischen Ozean (Valdivia) und im Pacific (Kofoid) gefunden worden. Einige wenige davon sind bis jetzt noch nicht beschrieben, obgleich die meisten von früheren Forschungen her bekannt sind. Es wird schwer halten, die Artengruppen nach ihrer geographischen Verbreitung in dem untersuchten Gebiete zu charakterisieren. Das kann vielleicht geschehen, wenn unser Material ganz bearbeitet sein wird, aber jetzt sicher noch nicht. Augenblicklich können wir nur die subtropischen Arten von denen der gemäßigten Gewässer unterscheiden, und die Arten des hohen Meeres von denen, die hauptsächlich längs der Küsten vorkommen.

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[1]) Scottish Geographical Magazine, December 1910.

Die verschiedenen Gruppen der planktonischen Algen passen sich in gänzlich von einander abweichender Weise den Lebensbedingungen im Meere an und müssen deshalb getrennt behandelt werden.

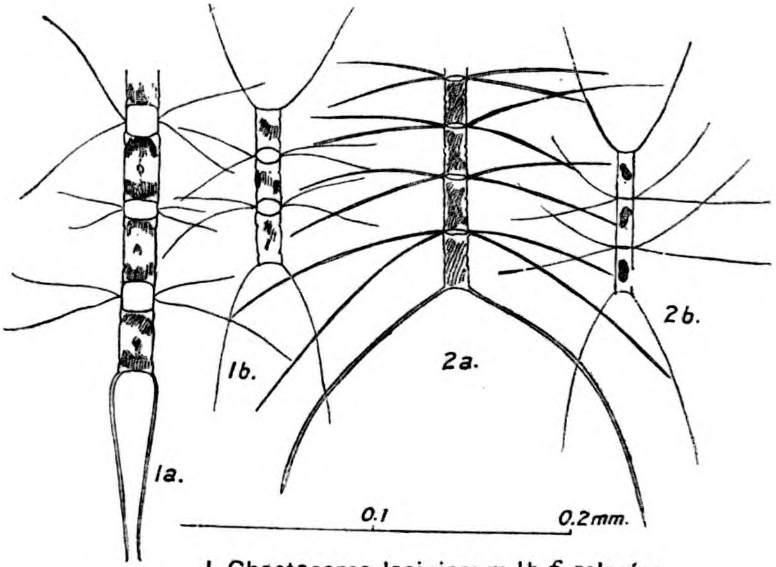
1. Die Cyanophyceae, oder blaugrünen Algen, haben verhältnismäßig wenig pelagische Vertreter, aber andererseits gehören dazu einige, die charakteristische Formen der tropischen Meere darstellen. Trichodesmium Thiebaulti besteht aus fadenförmigen Zellreihen, die in mehr oder weniger regelmäßigen, gelbbraunen Haufen zusammensitzen. Bei ruhigem Wetter kommen sie ganz an die Oberfläche hinauf, wo man sie mit bloßem Auge sehen kann; dann treiben sie manchmal in so dichten Massen zusammen, daß sie eine deutliche Schicht bilden. Die Art kommt nur in Meeresströmungen tropischen Ursprungs vor, und Cleve gab eine charakteristische Definition des tropischen Meeresplankton im Atlantik, als er es Desmoplankton nannte. Wir fanden es an allen Stationen von den Kanaren bis zu den Neufundlandbänken, und von dort bis zu den Küstenbänken um Irland.

Cyanophyceen werden in gemäßigten und kalten Meeren nicht gefunden, doch können einige Arten im Sommer wohl in schwach salzigen Gewässern, wie der Ostsee, vorkommen. Auch bilden andere Arten manchmal in flachen Süßwasserseen während der heißesten Jahreszeit die sogenannte „Wasserblüte".

2. Diatomeen kommen zu Zeiten in größeren Mengen vor als irgendwelche anderen planktonischen Algen. Sie werden in allen Meeren gefunden: von den polaren Gegenden, wo die Temperatur unter 0° ist, bis zu den Tropen, und an den Küsten sowohl wie auf hoher See. Die meisten Spezies sind auf die flachen Küstengewässer beschränkt. Sie bilden Dauersporen mit verdickten Zellwänden, die zu Boden sinken und so die Erhaltung der Art während der ungünstigen Jahreszeit sicher stellen. Indessen kommen einige Arten auch ausschließlich im offenen Meere vor.

Es gibt verhältnismäßig wenig Diatomeen, die im Atlantik für die tropischen und subtropischen Teile der hohen See typisch wären, obgleich einige von ihnen sehr charakteristisch sind. Coscinodiscus rex, die größte aller pelagischen Diatomeen, erscheint dem unbewaffneten Auge als gelbbraunes Bläschen von über 1 mm Durchmesser; der Zellinhalt zieht sich als dünne Schicht längs der fein skulpturierten Zellwandung hin. Planktoniella sol und Gossleriella tropica sind scheibenförmige Zellen mit eigentümlicher Schwebevorrichtung. Planktoniella besitzt einen aus zarten Teilen bestehenden Kragen, Gossleriella hat eine Krone aus feinen, kieselhaltigen Fibrillen.

Die Gattungen, die in den gemäßigten Meeren vorkommen (Chaetoceras, Rhizosolenia, Thalassiothrix) sind in ihrer Art ebenso gut für eine pelagische Existenz ausgerüstet, und ihre Schwebevorrichtungen zeigen ebensoviele Verschiedenheiten. Sie müssen ihre Oberflächen und Schwimmfähigkeit ebenso vergrößern, denn in den gemäßigten Meeren werden sie häufig in Strömungen von geringerem Salzgehalt und geringerer Dichte getrieben; dort vermehren sie sich oft ungeheuer. Außerdem ist noch zu erwähnen, daß verschiedene der ozeanischen Diatomeen, die als charakteristische Typen der kalten Meere gelten, in geringerer Anzahl selbst an den wärmsten Stationen gefunden wurden. Das ist besonders bei den Spezies der Fall, die in großer Menge sowohl im nördlichen wie im südlichen Eismeer vorkommen (Thalassiothrix longissima, Rhizosolenia hebetata f. semispina); sie können darum nicht als typische Beispiele bipolarer Verbreitung angesehen werden.



1. Chaetoceras laciniosum. 1b f pelagica
2 Ch. Schuettii 2b. f Oceanica

Fig. 11

Wichtige Diatomeen.

Die Grenze zwischen Küstenplankton und Hochseeplankton scheint in den warmen Meeren nicht so leicht zu ziehen zu sein, wie in den gemäßigten. In unseren Breiten verbringt ein Teil des Küstenplanktons während der dunkelsten Jahreszeit einige Monate im Ruhestadium, andere Spezies dagegen während des Sommers. Im zeitigen Frühjahr ist das wirkliche Küstenplankton auf die flachen Uferbänke beschränkt, aber im Laufe des Sommers und Herbstes folgen eine größere oder kleinere Anzahl von Gattungen den Oberflächenströmungen hinaus ins offene Meer; sie spielen dort jedoch, im Vergleich zu den ozeanischen Gattungen, die sich an Ort und Stelle entwickelt haben, nur eine ganz untergeordnete Rolle.

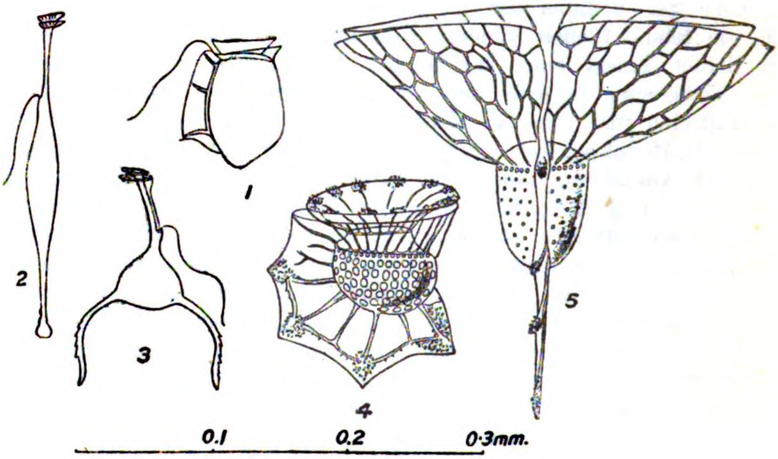
In wärmeren Gewässern scheinen die Diatomeen des Küstenplanktons längere Zeit außerhalb ihrer eigentlichen Gebiete bleiben zu können als bei uns. Nur in sehr wenigen der Planktonproben, die wir aus den Oberflächenschichten nahmen, fehlten Diatomeen, die eigentlich zur Küstenflora gehörten, gänzlich. Man findet sie gewöhnlich in kleinen Mengen, und sie haben bei weitem keine so kräftige Struktur, denn sie besitzen dünnere Zellwände und geringere Dimensionen als die entsprechenden aus den Küstengewässern. Trotzdem sind sie aber unzweifelhaft imstande, fortzubestehen. Ein charakteristisches Beispiel der langen Wanderungen seitens solch degenerierter Küstenformen bis in die hohe See konnten wir im Laufe unserer Untersuchungen feststellen. Südlich von Island fanden frühere Beobachter von Mai bis Juli und bis tief in den Herbst hinein eine Anzahl von degenerierten Küstendiatomeen, besonders Chaetoceras Schüttii und Ch. laciniosum, die zeitweilig in großen Mengen auftreten und zwar in Wasser, dessen hoher Salzgehalt es als unvermischtes Golfstromwasser charakterisiert (s. Fig. 11). Diese Formen unterscheiden sich vollständig von dem isländischen Küstenplankton, und es ist garnicht daran zu denken, daß die Algen etwa von den isländischen Küsten dorthinaus gewandert sein könnten. Nun fanden wir auf unserer Fahrt genau dieselben Spezies in ebendenselben Formen im Golfstrom wie im hohen Meere östlich von Nordamerika, so daß sie unzweifelhaft durch die Strömung aus den amerikanischen Küstengewässern herausgetragen worden sind. Sobald die Strömung sie an Örtlichkeiten bringt, wo ihnen die Existenzbedingungen zusagen, vermehren sich diese Diatomeen in ungeheurer Menge, aber sie haben die schwache Struktur und die kleinen Dimensionen, die Professor Gran als Zeichen der Degeneration ansieht.

3. Peridineen bilden neben den Diatomeen die Hauptmasse des Planktons, das wir mittels Schleppnetze erhalten. Bei weitem die meisten Spezies sind rein ozeanisch, und der größte Teil gehört warmen Meeren an. Auch finden wir hier eine viel größere Variation in der Zellorganisation als in gemäßigten Meeresteilen. Als Beispiel will ich die Familie der Dinophysiden erwähnen. Im nördlichen gemäßigten Atlantik wird diese Familie durch ein paar Spezies aus der Gattung Dinophysis vertreten (s. Fig. 12). Die verbreitetste, D. acuta, besteht aus einer zungenförmigen, zusammengepreßten Zelle, die mit zwei Cilien ausgestattet ist. Eine dieser Cilien wimpert frei an einer Seite längs einer Membran, die andere liegt geschützt zwischen zwei ringförmigen Membranen am Vorderende der Zelle. Die Alge hält sich in den oberen Schichten flottierend durch die Bewegungen ihrer haarförmigen Wimpercilie; der Körper ist verhältnismäßig schwer.

In warmen Meeren finden wir eine außerordentlich große Verschiedenheit dieses Typus. Bei einzelnen Gattungen entwickelt sich der Schwimmapparat aus verschiedenen Organen der Zelle. Bei der Amphisolenia ist die ganze Zelle in ein haarförmiges Gebilde ausgezogen, das am Vorderende auf einem kleinen Kopfe die ringförmigen Membranen trägt. Bei Triposolenia ist der mittlere Teil der Zelle rund, Kopf und Membranen sind an einem langen Halse

befestigt und hinten endigt die Zelle in zwei gebogenen dünnen Beinen, die nicht in derselben Ebene stehen.

Andere Gattungen haben noch beinahe dieselbe Zellform wie Dinophysis, aber die Membranen sind zu Schwimmvorrichtungen umgewandelt. In einigen Fällen ist die seitliche Membran am höchsten entwickelt, schließt den ganzen hinteren Teil der Zelle mit ein und wird dann durch sich verzweigende Rippen versteift (Ornithocercus magnificus). Bei anderen bilden die ringförmigen Membranen einen vollständigen Fallschirm, der ebenfalls durch Rippen versteift wird (Ornithocercus splendidus). Eine gleiche Variationsfähigkeit wird auch in anderen Familien gefunden, besonders bei Ceratium, der wichtigsten aller dieser Gattungen. Einige Spezies dieser Gattung variieren außerordentlich und können ihre Oberfläche je nach der Dichte des umgebenden Mediums vergrößern oder verkleinern. Die Expedition hat ausgezeichnetes Material zum Studium dieser Variationen mitgebracht; eine Spezies z. B. Ceratium platycorne, Fig. 13, zeichnet sich dadurch aus, daß ihre beiden hinteren Hörner in einen flachen, flügelähnlichen Schwimmapparat umgebildet sein können. An der nördlichen Grenze ihres Verbreitungsgebietes geht sie dagegen in eine Form mit ganz zylindrischen Hörnern über. Das war die Ursache dafür, daß diese Form früher als eine besondere Spezies, C. compressum, beschrieben wurde.



1. Dinophysis acuta. 2. Amphisolenia globifera. 3. Triposolenia bicornis. 4. Ornithocercus magnificus. 5. Ornithocercus splendidus.

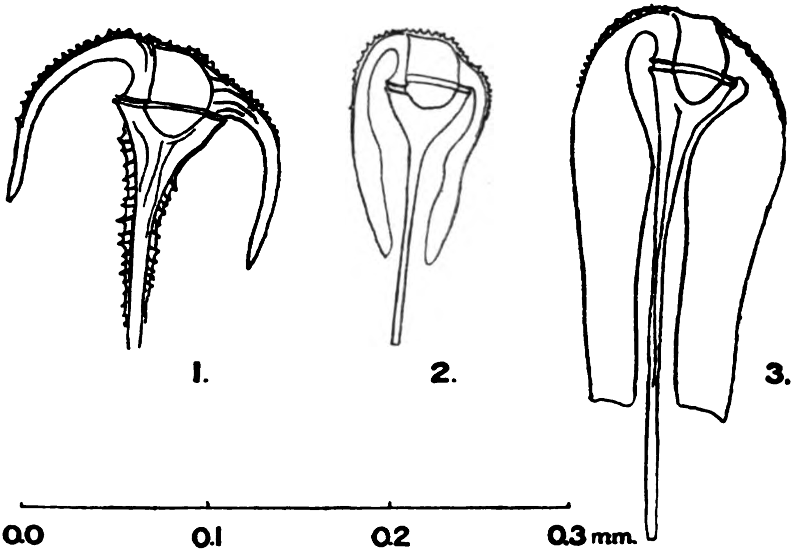
Fig. 12

Wichtige Peridineen.

Alle diese Organismen kann man mit den gewöhnlichen Schleppnetzen aus Müllerseide fangen, deren Maschen 0,04—0,06 mm im Durchmesser betragen. In den Küstengewässern kommen sie manchmal in großen Mengen vor, aber im offenen Atlantik findet man sie nur vereinzelt, gewöhnlich von allen

Spezies zusammen nicht mehr als zehn Exemplare in einem Liter; und selbst das nur in den Schichten nahe der Oberfläche, wo die Existenzbedingungen am günstigsten sind.

Die größere Hälfte der pflanzlichen Substanz in diesen ozeanischen Gewässern besteht aus Organismen von 0,02 mm Durchmesser oder noch weniger, die gewöhnlich durch die Maschen selbst der feinsten Schleppnetze hindurchgehen. Und das wertvollste Ergebnis unserer Expedition in botanischer Hinsicht war, daß wir die Möglichkeit gezeigt haben, diese Organismen während der ganzen Fahrt lebend zu untersuchen und die Mengen der verschiedenen Spezies, die in je einem Liter Seewasser in verschiedener Tiefe vorkommen, zu bestimmen.



Ceratium platycorne.

Fig. 13

1. F. compressa. 2 3 F. normalis.

Schon bei Gelegenheit der Challenger-Expedition machte Sir John Murray auf die Wichtigkeit dieser Organismen aufmerksam, als er fand, daß der Mageninhalt der Salpen zum größten Teile aus diesen kleinen Lebewesen bestand; und er konnte auch mehrere Male ihr Vorkommen im Seewasser nachweisen.

Später brachte Hensen an den Schleppnetzen Verbesserungen an, indem er augenscheinlich annahm, daß er nun sicher Exemplare aller Lebewesen, die im Meere flottieren, erhalten würde. Als er aber dann nach seiner großen Expedition 1889 nicht imstande war, greifbare Mengen kleinerer Organismen vorzuzeigen, begannen die Leute an deren Vorkommen, oder zum mindesten an ihrer Bedeutung zu zweifeln. George Murray hat dann von neuem darauf hingewiesen, daß die hauptsächlichste Familie, die Kalk-Flagellaten, ganz allgemein durch sämtliche Meere verbreitet sind. Und Lohmann, dessen Plankton-Untersuchungen viel zur Erweiterung unserer Kenntnis und Verbesserung unserer Methoden beigetragen haben, stellte systematische Forschungen mit Filtern feiner Konstruktion an, besonders im Mittelländischen Meer und in der Ostsee, um ihr Vorhandensein zu beweisen. Er führte auch zum Studium der kleinsten Organismen eine kleine Handzentrifuge ein, die in planktonreichen Gewässern sehr gute Dienste geleistet hat.

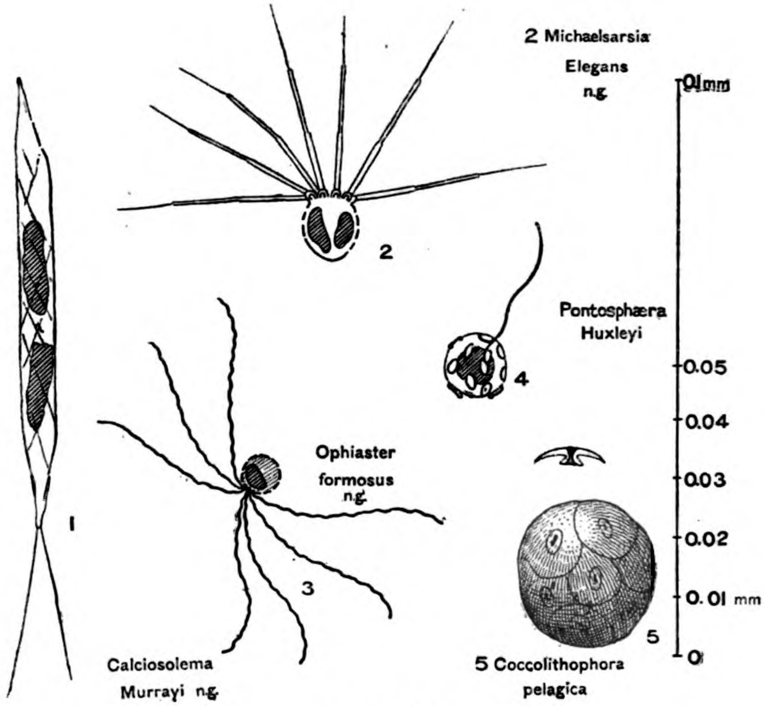
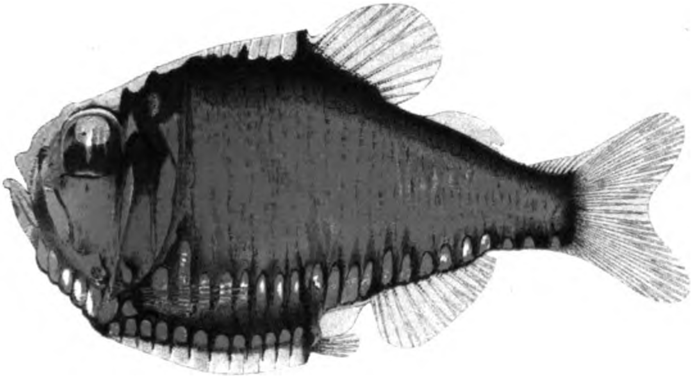

2 Michaelsarsia Elegans n.g.
0.1mm
2
Pontosphæra Huxleyi
4
0.05
0.04
Ophiaster formosus n.g.
0.03
I
0.02
3
0.01 mm
5
0
Calciosolema Murrayi n.g.
5 Coccolithophora pelagica

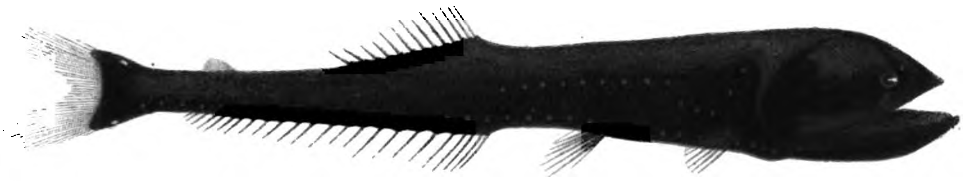
Fig. 14

Neue Algenformen des Zentrifugenplanktons („Nannoplankton“ Lohmann).

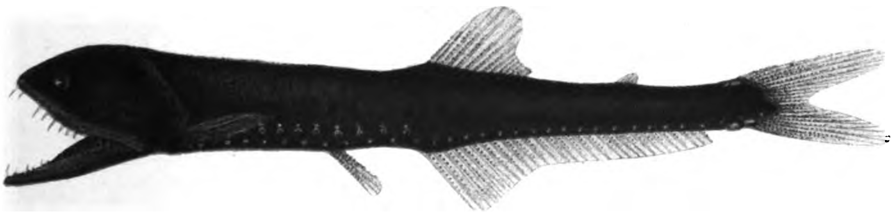
Während der Michael Sars-Expedition gebrauchten wir außerdem eine große, mit Dampf getriebene Zentrifuge, die uns instand setzte, mehr als ein Liter Wasser auf einmal zu zentrifugieren. Die Wasserproben wurden mit Wasserflaschen aus verschiedenen Tiefen geholt; und gewöhnlich wurden 300 ccm jeder Probe mit der Zentrifuge behandelt. Das Wasser am Grunde der Zentrifugengläser, das die planktonischen Algen enthielt, wurde mittels einer kleinen Handzentrifuge konzentriert, sodaß man schließlich den ganzen Inhalt in einem einzigen Wassertropfen unter das Mikroskop legen konnte.



ARGYROPELECUS AFFINIS, GARM.



GONOSTOMA GRANDE, COLLETT.



GONOSTOMA ELONGATUM, GTHR.

HJORT

Verlag von Dr. Werner Klinkhardt.
Leipzig.

Auf diese Weise konnten wir das quantitative Vorkommen der verschiedenen Species in verschiedenen Tiefen während der ganzen Fahrt studieren. Es gelang uns, eine ganze Reihe bis dahin unbekannter Formen, besonders unter den Kalk-Flagellaten, zu entdecken (Fig. 14.) Und durch unsere Untersuchungen bekamen wir auch einen viel klareren Begriff von der Verteilung der pflanzlichen Organismen in bezug auf die Tiefe.

Wenn wir zusammenfassen wollen, so sind unsere Hauptresultate folgende:

1) Im offenen Atlantik ist die Menge des Planktons viel geringer als in den Küstengewässern.

2.) An den meisten Stationen, wo Untersuchungen angestellt wurden, wurde die Hochstzahl von pflanzlichen Organismen bei ungefähr 50 m gefunden. Gewöhnlich war das Vorkommen in unmittelbarer Nähe der Oberfläche selten, schien aber bei 10 m beinahe ebenso häufig wie bei 50 m zu sein. Es fand sich also auf der ganzen Strecke von 10 m bis 50 m ungefähr die gleiche Anzahl von pflanzlichen Organismen.

In 75 m Tiefe betrug die Anzahl nur noch die Halfte derer bei 50 m und in 100 m gar nur noch v ein Zehntel.

Das war der Fall in Meereswasser. War aber Küstenwasser beigemischt und bestand ein deutlicher Unterschied zwischen den Oberflächen- und den tieferen Schichten, so waren erstere verhältnismässig reicher an pflanzlichen Organismen.

3.) Die verschiedenen Species sind, was die Tiefe anbelangt, jede in ihrer eigenen, charakteristischen Weise verbreitet. Die Peridineen halten sich nahe der Oberflache, die Diatomeen ziehen die tieferen Schichten vor, während die Coccolithophoriden eine Zwischenstellung einnehmen.

4.) Die Anzahl der lebenden Pflanzenzellen im offenen Atlantik variiert in den dichtest belebten Schichten (10 bis 50 m) gewöhnlich zwischen 3000 bis 12000 pro Liter Seewasser. Davon sind die Halfte Coccolithophoriden, das übrige Peridineen mit ein paar nackten Flagellaten und verschwindend wenigen Diatomeen.

(Schluss folgt.)

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EARLY DISCOVERIES REGARDING THE PARASITE OF ORIENTAL SORE.

(WITH AN ENGLISH TRANSLATION OF THE MEMOIR BY P. F. BOROVSKY : " ON SART SORE." 1898.)

BY
CECIL A. HOARE, D.Sc.,
Wellcome Bureau of Scientific Research, London.

ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE
MANSON HOUSE, 26, PORTLAND PLACE, LONDON, W.1

Peter Borovsky (1863-1932).
From a photograph taken in 1895.

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INTRODUCTION.

The history of the discovery of the parasites causing oriental sore and kala-azar has already been discussed in a number of text-books of medical protozoology (*e.g.*, LAVERAN'S *Leishmanioses*, 1917; and WENYON'S *Protozoology*, 1926) and in some of the special papers dealing with the leishmaniases. The narrative given in different publications varies as regards both completeness and degree of accuracy, the latter depending upon the sources of information used by the writers and upon the interpretation of the available data.

In the case of oriental sore the first observer who actually saw the parasite, now known as *Leishmania tropica*, was CUNNINGHAM (1885); WRIGHT (December, 1903), however, is credited with the first correct description of this organism. Since the parasite of kala-azar, now known as *L. donovani*, was also discovered in the same year by LEISHMAN (May, 1903), the elucidation of both cutaneous and visceral leishmaniasis is generally associated with the year 1903. In LAVERAN'S important monograph on the leishmaniases this is emphasized in the opening sentence as follows: " La découverte des Protozoaires connus sous le nom de *Leishmania* ne date que de 1903 " (LAVERAN, 1917: p. 1).

A few years ago PAWLOWSKY (1927, 1931) drew attention to the fact that the parasite of oriental sore was first correctly described and identified as a protozoon in 1898, by a Russian military surgeon, P. F. BOROVSKY, whose observations were described in a memoir " On Sart Sore "* published in *Voenno-Medicinskij Žurnal*† [= Military-Medical Journal] (St. Petersburg), Part CLXXXXV, Book 11, November, 1898. This paper, being written in Russian, in a journal with a limited circulation, remained unknown outside Russia,‡ and even in the country of its origin BOROVSKY's discovery was not properly appreciated until quite recently (YAKIMOFF, 1915 ; PAWLOWSKY, 1927) though references to it and quotations from the paper appeared in some earlier publications (MARZINOWSKY and BOGROW, 1904 ; MARZINOWSKY, 1909, 1912 ; PETERSEN, 1912).||

At present BOROVSKY's paper is available to readers not conversant with the Russian language only in the form of a short extract translated into German by PAWLOWSKY (1931). In Russia itself the journal in which the memoir appeared is now a bibliographical rarity, but part of the paper has been made accessible to a wider circle of Russian readers by the publication of extracts from it in commemoration of the 40th year of BOROVSKY's scientific career (ORLOV, 1927).

One of the objects of the present paper is to give an account of BOROVSKY's observations and to assign his discovery to its proper place in the history of tropical medicine and parasitology. Since the perusal of the original literature on the aetiology of the leishmaniases has revealed a number of new facts of historical interest, it is proposed at the same time to give a brief account of the work that preceded and followed BOROVSKY's discovery (with the exception of those investigations in which these diseases were attributed to bacteria).

The other object of this paper is to provide an unabridged English translation of BOROVSKY's memoir, thereby placing it in its entirety at the disposal of the English-reading public for the first time. In view of the inaccessibility of the original both because of its being out of print and because of language difficulties, it is hoped that future historians of medical zoology will be able to make use of this translation as an equivalent of the original text. To this end particular care has been taken to make the translation as literal as is consistent with correct English.

*" Sart sore " and " Pendeh sore " are two local names under which oriental sore is known in Turkestan. They are derived from the *Sarts*, a native tribe in the former Syr-Daria and Ferghana territories, and from *Pendeh*, a town in the former Transcaspian province, respectively.

†The transliteration is that adopted by the Russian Academy of Sciences. It has been used by me for names which have hitherto appeared in Russian only. For names of Russian authors who have employed other methods of transcription I have adhered to their own spelling.

‡Only brief and inadequate mention of BOROVSKY's discovery was made by PETERSEN (1912a) and by YAKIMOFF (1915a), the latter stating that " il a le mérite d'avoir reconnu, le premier, dans ces parasites des protozoaires." (*Loc. cit.*, p. 500.)

||I have to acknowledge my indebtedness to Prof. W. L. YAKIMOFF, of Leningrad, for the loan of a number of reprints of Russian papers referred to above, which are unobtainable in this country.

I was unable to find the required issue of the "*Voenno-Medicinskij Žurnal*" in any of the scientific libraries of this country, but was fortunate enough to receive a copy of this rare publication from Prof. F. WALCKER, M.D., Director of the Library of the Military Medical Academy, Leningrad, to whom I wish to express my deepest gratitude for this service.

In addition to a review of the history of the discovery of the parasite causing oriental sore, I have appended a note dealing with the views of K. SHULGIN (1902) on the transmission of this disease. Although SHULGIN was the first to incriminate blood-sucking insects as vectors, his observations have passed almost unnoticed and remain practically unknown.

BOROVSKY'S PREDECESSORS.

The discovery of the causative agent of oriental sore is generally attributed to CUNNINGHAM (1885), who was certainly the first to devote his attention to other elements than the bacteria associated with the lesion, some of which were at that time believed to play a part in the production of the disease. In sections of a sore (" Delhi boil ") fixed in alcohol and stained with gentian violet CUNNINGHAM found numerous cells measuring on an average 12·6 by 8·8μ and varying in form. These cells contained rounded elements, referred to as " nucleoid bodies," which stained uniformly violet or blue, and varied in number and size. In some of the cells only " a single nucleoid mass " was present, in others " a few of very various sizes," while in others again " a large number of minute and fairly equal sized ones were thickly scattered throughout the entire cell."

CUNNINGHAM regarded these cells as " parasitic bodies " responsible for the disease, and referred them to the Mycetozoa or " slime-fungi." The cells themselves were believed to be the " parent plasmodia or amoebae " [= plasmodia] of a " Monadinic organism," while the " nucleoid bodies " within them were supposed to represent " sporoid bodies," or stages of development of " zoocysts or sporocysts " [= spores]. It is evident from the text that CUNNINGHAM had in mind a parasitic mycetozoon of the type of *Plasmodiophora*, to the plasmodial stage of which his figures bear some resemblance.

Amongst the elements described and depicted by CUNNINGHAM some, like the small " nucleoid bodies " of equal size, undoubtedly represented Leishman-Donovan bodies, while others—large single " nucleoid bodies " and cell-inclusions of unequal size—were either artifacts or products of degeneration. It would thus appear that CUNNINGHAM was actually the first to have *seen* the parasites of oriental sore enclosed in the tissue-cells of the host, but he entirely misunderstood and misinterpreted their nature, for he regarded the host-cell (macrophage) as the parasite, while the leishmanias within it—which revealed no structure owing to the crude technique employed—were interpreted as spores developing in the parent plasmodium.

These findings were later confirmed by FIRTH (1891), who added nothing new to CUNNINGHAM's description of the " parasitic bodies," but stated that he " always regarded them as sporozoa and in 1887 went so far as to suggest . . . the name *sporozoa furunculosa* to indicate their peculiar pathological influence." In the legend to his Fig. 5 FIRTH refers to the elements evidently depicting the macrophages with enclosed leishmanias as " multinuclear bodies " which, he says, are " the spore-like bodies alluded to in the text." Since these bodies are also called " sporozoa " in the text, and " sporozooid bodies " in the title of the paper, it is clear that all these designations were regarded by him as equivalent.

I have dwelt on FIRTH's nomenclature at some length because certain authors have accepted " *sporozoa furunculosa* " as a binominal Linnaean name.* However, it is clear from the context and from the examples quoted above that FIRTH himself employed the name " *sporozoa furunculosa* " merely as a descriptive Latin medical term, the English equivalent of which would be *furunculous* (or *furuncular*) *sporozoa*, or—in the author's own words—" spore-like bodies " associated with boils. However, if formal arguments against the validity of FIRTH's nomenclature are required, it may be pointed out that the name *Sporozoa*, having been given to a class by LEUCKART in 1879, is not available for a genus; furthermore, in the original text the name " *sporozoa*," though written in italics, begins with a small initial letter and appears in the plural form, with which " *furunculosa* " is in agreement. The last two items constitute an infringement of Art. 8 of the International Rules of Zoological Nomenclature, according to which " A generic name must consist of a single word . . . written with a capital initial letter, and employed as a substantive in the nominative singular."

BOROVSKY'S OBSERVATIONS.

BOROVSKY commenced his researches on the aetiology of oriental sore (" Sart sore ") in 1894 and published the results in 1898. He was fully conversant with the works in which the causative agent was sought amongst the bacteria, but evidently knew nothing about the publications of CUNNINGHAM and FIRTH. Though he also cultivated bacteria from the sore, he at once realized that they were of no aetiological significance and turned to the investigation of young, non-ulcerating sores.

He examined the " juice " from the sore in hanging drop preparations, made smears of the scrapings—fixed with absolute alcohol and ether and stained by Loeffler's method—and also cut and stained sections of excised sores after fixation in Zenker's fluid. In all these preparations he found numerous small spherical, oval or fusiform corpuscles, measuring about 1·5 to 2·0μ in diameter. In each of these bodies BOROVSKY distinguished a nucleus,† while in many he detected a " process " running from the nucleus to the periphery of the body. In smears the parasites—for BOROVSKY immediately recognized the " corpuscles " as such—were either free or packed into " spheres," but in sections the majority were enclosed within the lymphoid or epithelioid cells of the host-tissues. Multiplication of the parasites was said to take place by simple fission, by a form of multiple division, and by budding. Attempts were made to cultivate the organisms, but these were unsuccessful.

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*As far as I was able to ascertain, BLANCHARD (1904) was the first to insist on its validity.

†Curiously enough, MARZINOWSKY and BOGROW (1904a) and later MARZINOWSKY (1912), in their comments on BOROVSKY's work, erroneously imply that he failed to detect the presence of the nucleus.

BOROVSKY recognized the parasites as " unicellular organisms," which he referred to the " class of protozoa," and concluded that " Sart sore is not caused by any kind of bacteria, but by organisms of a higher order, *viz.* protozoa."

If BOROVSKY's data are examined from the point of view of our present knowledge, it will be seen that he not only gave an accurate description of the parasite of oriental sore,* but also established its true relation to the elements of the host's tissues. There can be little doubt that the " process " seen near the nucleus of the parasite represents the rod-shaped kinetoplast (=kinetonucleus),† while the " lymphoid " cells harbouring the parasites are evidently the macrophages.

To BOROVSKY thus belongs the credit of being the first to give a recognizable description of *Leishmania tropica*—and indeed of leishmanias in general—and of assigning it to the Protozoa.

It is inevitable that some minor errors of interpretation should have occurred in BOROVSKY's account, but if it is taken into consideration that his investigations were carried out independently, in a field in which he had no previous experience, it is surprising that these errors are so few and insignificant.

The foregoing is only a brief statement of BOROVSKY's findings. For full particulars of his investigations and for their interpretation the reader is referred to the translation of the paper " *On Sart Sore* " appearing in Appendix II, accompanied by the translator's comments. In addition to the observations leading to the elucidation of the aetiology of oriental sore, BOROVSKY has given a very accurate account of the clinical course and histopathology of this disease.

BOROVSKY'S SUCCESSORS.

BOROVSKY's investigations were closely followed by K. SHULGIN, his colleague at the Tashkent Military Hospital, who (SHULGIN, 1902) was soon able to confirm all BOROVSKY's results in the case of " Pendeh sore," which was prevalent in south-eastern Turkestan.

Though the history of the subsequent investigations on the aetiology of oriental sore is fairly well known, I have found—in the course of a careful study of the literature on this subject undertaken in connexion with the present inquiry—that a number of important data have been omitted or misinterpreted. In order to render this historical review as complete as possible, therefore, I propose to give a brief survey of the work leading to the establishment of *Leishmania tropica* in the position it now occupies.

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*In this connexion it is interesting to note that YAKIMOFF (1915) had seen typical leishmania in one of BOROVSKY's original preparations of oriental sore, made in the 'nineties and presented to YAKIMOFF in 1913.

†In BOROVSKY's Fig. 1 (see plate facing p. 84), depicting the parasites, this structure cannot be detected.

While BOROVSKY was undoubtedly the first to give a recognizable account of this parasite, the details of its structure as it is known at present were first revealed by WRIGHT (1903). However, the actual description of the morphology of the parasite adds nothing new to BOROVSKY's account, for WRIGHT refers to the nucleus and kinetoplast merely as " a larger and a smaller lilac-coloured mass " respectively, and only *assumes* that these structures " are of the nature of nuclei," whereas BOROVSKY definitely described the nucleus as such, and only failed to interpret the nature of the kinetoplast (his " process "). On the other hand, WRIGHT's photomicrographs provide the first accurate illustration of the cytological details of the parasites in question. These were identified by him as Protozoa and tentatively referred to the Microsporidia, under the name *Helcosoma tropicum*. WRIGHT evidently knew nothing about BOROVSKY's paper and (since he does not refer to them) it may be inferred that he was either unaware of the works on the parasite of kala-azar published in the course of the same year (1903) or did not appreciate their bearing upon his own investigation.

In 1904 there appeared two versions (Russian and German) of a paper by MARZINOWSKY and BOGROW (1904, 1904*a*) in which these observers give a correct description of the parasite of oriental sore, illustrated by photomicrographs. They refer to the nucleus and kinetoplast as macro- and micronucleus respectively, their interpretation thus coinciding with the conception of those authors who regarded the Trypanosomidae as binucleate organisms. They furthermore expressed their firm conviction that the parasite was a protozoon very closely related to *Trypanosoma*, though differing from it in certain characters. It is thus seen that MARZINOWSKY and BOGROW recognized the true affinities of the parasite of oriental sore, for which they proposed the name *Ovoplasma orientale*. Though the Russian authors arrived at this conclusion quite independently, BLANCHARD, whose paper appeared in May, 1904, was actually the first to draw attention to the close relationship of this parasite to the trypanosomes, but his opinion was based on the knowledge of LEISHMAN'S work on the parasite of kala-azar, as will be shown below.

It is not generally known that although MARZINOWSKY and BOGROW'S papers were published nearly a year later than WRIGHT'S, the investigations of the Russian authors and their conclusions were entirely independent of those of WRIGHT. This is clear not only from the dates appearing in the corresponding writings,* but also from the testimony of MESNIL (1904), who, in his review of WRIGHT'S paper, states that parasites identical with those described by WRIGHT

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*The case described by WRIGHT first came under his observation on July 28th, 1903, while that which provided the material for MARZINOWSKY and BOGROW was examined by them between the end of May and the end of June, 1903.

(December, 1903) had already been seen by him in November, 1903, in preparations of an oriental sore received from MARZINOWSKY, a fact which is also recorded by the Russian observers (MARZINOWSKY and BOGROW, 1904*a*). From the work of these authors it is also obvious that, like WRIGHT, they had no knowledge of the preceding investigations on the aetiology of kala-azar. They were, however, familiar with BOROVSKY's memoir, but their paper shows a certain tendency to belittle his achievements, while some of his observations are even misrepresented (cf. footnote on p. 70). This attitude is also maintained by one of these authors in a subsequent paper (MARZINOWSKY, 1912).

The remaining publications on the parasite of oriental sore to be considered are those which led to the final elucidation of its morphology and to the determination of its systematic position as established at present. Attention has already been drawn to the fact that the investigations reviewed above were conducted independently and in ignorance of similar work carried out on kala-azar. However, the close resemblance between the causative organisms of this disease and of oriental sore was soon recognized, and thereafter the study of the two parasites began to be correlated. In order to understand the vicissitudes through which the classification of the parasite of oriental sore has passed, it is, therefore, necessary to make a digression and consider briefly the earlier work on the identity of the parasite of kala-azar.

When first discovered by LEISHMAN (1903) the parasite responsible for kala-azar* was referred to the trypanosomes and correctly described as possessing a macro- and a micro-nucleus [= kinetonucleus or kinetoplast]. LAVERAN (1903), however, concluded that this parasite represented a piroplasm and—with MESNIL—named it *Piroplasma donovani*. ROSS (1903) took the same view—though independently—as CUNNINGHAM did with regard to the parasite of oriental sore, and considered the entire host-cell (" matrix ") with the enclosed organisms, which he interpreted as " spores," to be the parasite, and referred it to the Sporozoa, emending LAVERAN and MESNIL's name to *Leishmania donovani*, under which it has been known ever since.

MESNIL (1904), who has made many valuable contributions to our knowledge of pathogenic protozoa in his critical reviews of the current literature, was the first to note the striking resemblance between *Helcosoma tropicum* and *Piroplasma donovani*, and suggested that the former should be placed " tout près des *Piroplasma*." The morphological similarity between the two parasites was confirmed by LEISHMAN (1904) and CHRISTOPHERS (1904), the former maintaining his belief in the flagellate nature of the parasite of kala-azar and the latter regarding it as a microsporidium. The position was then examined by BLANCHARD (1904), who pointed out that there was not a single character distinguishing the parasite of oriental sore from that of kala-azar and, accordingly, referred the former to the same genus under the name *Leishmania furunculosa* (Firth, 1891), in the belief that FIRTH's name " *sporozoa furunculosa* " was a valid binominal designation.* BLANCHARD followed LEISHMAN in admitting the possibility of *Leishmania* representing some stage of a trypanosome.

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*Though the Leishman-Donovan bodies were actually first seen by MARCHAND (1903), he did not consider them to be parasites, but regarded them as the product of degenerated cell nuclei. However, later MARCHAND and LEDINGHAM (1904) recognized that the structures previously observed by the first-named author were really the parasites described by LEISHMAN and others in 1903.

Shortly afterwards ROGERS (1904, 1904a) succeeded in cultivating *L. donovani* and demonstrating its flagellate stage. This observation led him to amplify LEISHMAN's view and to regard the Leishman-Donovan bodies as a definite stage in the life-history of a trypanosome. MESNIL (1904a) attempted to reconcile his own views with those of ROGERS, on the basis of SCHAUDINN's theory, by accepting two stages of development in the leishmanial parasite, one being an endoglobular piroplasm and the other a trypanosome. In a " Discussion on the Leishman-Donovan Body " at the 72nd Meeting of the British Medical Association, LEISHMAN (1904a) compared these bodies to the " resting forms " of *Herpetomonas muscae-domesticae*. A further step towards the recognition of the affinities of *L. donovani* with the insect-flagellates was made by MESNIL (1904b), who, in reviewing ROGERS's paper on the cultural forms, stated that these were more like *Crithidia* or *Herpetomonas* than *Trypanosoma*. ROGERS (1906) arrived at the same conclusion and proposed to rename the parasite " *Hepatomonas* [obvious *lapsus calami* for *Herpetomonas*] of Kala Azar," a suggestion formally endorsed by MESNIL (1906) in emending the name to *Herpetomonas donovani* (L. & M.), the same amendment having been made later, but apparently independently, by PATTON (1908). The name of this parasite was again changed, to *Leptomonas donovani* (L. & M.), by MESNIL (1909).

In spite of all this evidence in support of the flagellate nature of the leishmanias, LÜHE (1906) in his systematic survey of the blood-inhabiting protozoa attached these parasites to the piroplasms. As far as I have been able to ascertain, this author was the first to adopt the name *Leishmania tropica* (Wright, 1903)† for the parasite of oriental sore, rejecting FIRTH's name " *sporozoa furunculosa*‡ as invalid on account of its plural form (cf. p. 70). In conformity with *Herpetomonas donovani*, PATTON (1909) transferred the parasite of oriental sore to the same genus, under the name *Herpetomonas tropica*, but later he (PATTON, 1922) revived FIRTH's designation and suggested the name *Herpetomonas farunculosa.*‖ Amongst the names given to this parasite the following should also be mentioned: *Leishmania wrighti* proposed by NICOLLE (1908a) and *Crithidium* [*sic*] *cunninghami* and *Leishmania cunninghami* by CARTER (1909). The last three names were introduced with an utter disregard of prior claims.

*The case against the validity of this name has been dealt with above (p. 70).

†This name was later suggested by WOODCOCK (1909), evidently in ignorance of LÜHE's earlier amendment.

‡LÜHE erroneously attributed this name to CUNNINGHAM.

‖This spelling is an obvious *lapsus calami*.

The flagellate nature of *L. tropica* was demonstrated in cultures for the first time by NICOLLE (1908), thus finally establishing its morphological, if not specific, identity with *L. donovani.*

NOMENCLATURE OF LEISHMANIA.

As far as I am aware, the complete synonymy of *L. tropica* and *L. donovani* has never been published. The following revised lists, which contain all the names I have been able to trace under which these parasites have been described, can serve as a brief summary of the foregoing historical review.

(1) ***Leishmania tropica*** (Wright, 1903) Lühe, 1906 (*nec* Woodcock, 1909).
Synonyms :—
- " Mycetozoa " Cunningham, 1885.
- " *sporozoa furunculosa* " Firth, 1891.
- " Protozoa " Borovsky, 1898.
- *Helcosoma tropicum* Wright, 1903.
- *Leishmania furunculosa* (Firth, 1891) Blanchard, 1904.
- *Ovoplasma orientale* Marzinowsky & Bogrow, 1904.
- *Leishmania wrighti* Nicolle, 1908.
- *Crithidium cunninghami* Carter, 1909.
- *Leishmania cunninghami* Carter, 1909.
- *Herpetomonas tropica* (Wright, 1903) Patton, 1909.
- *Herpetomonas farunculosa* (Firth, 1891) Patton, 1922.

(2) ***Leishmania donovani*** (Laveran & Mesnil, 1903) Ross, 1903.
Synonyms :—
- *Piroplasma donovani* Laveran & Mesnil, 1903.
- " *Hepatomonas* of Kala Azar " Rogers, 1906.
- *Herpetomonas donovani* (Laveran & Mesnil, 1903) Mesnil, 1906 (*nec* Patton, 1908).
- *Leptomonas donovani* (Laveran & Mesnil, 1903) Mesnil, 1909.

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APPENDIX I.

P. F. BOROVSKY (1863-1932): A BIOGRAPHICAL NOTE.

PETER FOKITCH BOROVSKY was born in 1863 at Pogar, in the Government of Chernigov, Russia. He studied medicine at the University of Kiev and at the Military Medical Academy in St. Petersburg, whence he graduated as an army doctor in 1887. Having specialized in surgery BOROVSKY obtained the degree of Doctor of Medicine in 1891 for a thesis entitled: *Contributions to the Study of Tuberculosis of the Bones and Joints* (St. Petersburg). In 1892 he was appointed to Turkestan, in charge of the Surgical Department and Bacteriological Laboratory of the Tashkent Military Hospital.

BOROVSKY's early researches in Turkestan were devoted to the elucidation of the aetiology of "Sart sore," which is one of the local names for oriental sore. His work was conducted in a small laboratory with poor equipment, the most valuable of which, a Zeiss microscope with an oil-immersion lens, was BOROVSKY's private property brought by him from St. Petersburg.

The results of these investigations were published by BOROVSKY in 1898, in a paper "On Sart sore," in *Voenno-Medicinskij Žurnal* [= Military-Medical Journal], in which he established the protozoal nature of the causative agent of oriental sore. Unfortunately, this work was destined to be BOROVSKY's only incursion into the realms of protozoology, for at that period the demand for surgeons in Turkestan was so urgent that he was compelled to devote himself entirely to surgery. In the course of his subsequent career BOROVSKY, as Professor of Clinical Surgery in the State University of Middle Asia, was engaged in teaching, as well as in clinical and research work. He died in Tashkent, where he had spent 40 years of his working life, on December 16th, 1932, at the age of 69.

The accompanying portrait (Frontispiece), taken in 1895, represents BOROVSKY—wearing the uniform of a medical officer in the Imperial Russian Army—at the age of 32, at the period when his researches on oriental sore were being conducted. The original portrait was given to the late Prof. G. H. F. NUTTALL, F.R.S., by Prof. E. N. PAWLOWSKY, of the Military Medical Academy, Leningrad, for inclusion in the "Portrait Gallery" of parasitologists at the Molteno Institute, Cambridge, and has been kindly placed at my disposal by Prof. D. KEILIN, F.R.S. The biographical data for this note were compiled from articles by I. I. ORLOV (*Pensée Méd. Uzbéquistane*, **2**, 1927, p. 5), E. N. PAWLOWSKY (*Ibid.*, p. 16), L. ISSAEV (*Med. Parasitol. & Parasit. Dis.*, Moscow, **1**, 1933, p. 277) and from two anonymous obituary notices (*Ibid.*, p. 287, and *Münch. med. Wschr.* **80, 1933**, p. 518).

APPENDIX II.

ON SART SORE.[1]

BY

P. F. BOROVSKY,

Junior House Surgeon, Bacteriological Department of the Tashkent Military Hospital.

p. 925 Sart sore is not widely distributed in Tashkent; it occurs only sporadically and new arrivals in the country do not invariably contract the disease as in the case of Pendeh sore, Aleppo boil, etc. The sores very rarely appear in the form of a multiple eruption; in most cases two or three sores occur, while solitary sores are not uncommon. Sart sore is thus more restricted in its distribution than Pendeh sore and its incidence amongst the troops is not of an epidemic character. Nevertheless, judging from the clinical and the anatomico-pathological pictures described by HEIDENREICH[2] and by RAPTSCHEWSKY, Sart sore is probably identical with Pendeh sore. It may therefore be assumed that the cause must be the same, though the conditions for the manifestation and spread of the infection are different. Moreover, in the Murgab valley itself the disease is not uniformly distributed, according to the investigations of RAPTSCHEWSKY (*Voenno-Medicinskij Žurnal*, 1889, Book VIII). HEIDENREICH and RAPTSCHEWSKY differ in their conclusions both as regards the cause of Pendeh sore and the method of its dissemination.

p. 926 On perusing both investigations one is forced to conclude that HEIDENREICH has investigated unsuitable old cases which had already become ulcerated, and that consequently the results obtained were doubtful. Thus,

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[1] [*Published in: Voenno-Medicinskij Žurnal* (= *Military Medical Journal*), *St. Petersburg, November,* 1898, *Part clxxxxv, Book* 11 (76*th year*) *pp.* 925-941, 2 *text-figs.* (*In Russian.*)

Translated from the Russian text by C. A. HOARE.

The pagination of the original text is indicated in the margins; the annotations in italics between square brackets—both in the text and in the footnotes—are interpolated by the translator: those not distinguished in this way are found in the original.]

[2] [*In some publications this name is spelt "Heydenreich."*—C.A.H.]

Heidenreich[3] says : " if the end of a platinum wire is introduced into the fluid issuing from a scab subjected to pressure, and if a stab is made with this infected wire into sterile [*nutrient gelatin*][4] in a sterile test-tube it is sometimes possible, after several days, to obtain a culture of a special micrococcus." In view of this statement one can understand the scepticism regarding the " micrococcus Biskra, **Duclaux** et **Heidenreich**," especially since **Raptschewsky** has obtained different results in his investigation. On account of the controversy regarding the aetiology of " oriental sore," and with the object of ascertaining whether Sart sore is identical with Pendeh sore, we undertook at the end of 1894 a bacteriological and anatomico-pathological investigation. The material for the investigation was provided partly by hospital patients and partly by out-patients. Most of the cases selected were in the early period, *i.e.* in the non-ulcerating stage, the importance of which was rightly pointed out by **Raptschewsky**.

The investigation was carried out with long intervals owing to lack of suitable material. Frequently several months would elapse before a single suitable case was encountered, and this was due not so much to the rareness of the disease as to the fact that patients in the first period of the disease pay little attention to it, since at the beginning it causes no discomfort, and therefore in most cases they apply for assistance only during the period of ulceration.

THE CLINICAL COURSE OF SART SORE.

In the initial phase of its development Sart sore appears in the form of a nodule elevated above the surface of the skin and perceptible both to *p. 927* the eye and to the touch. The nodule, which is of a dark red hue, passes imperceptibly into the healthy tissue of the skin. Palpation is not painful ; the patient feels no discomfort, except a slight itching, and even this is not always experienced. After 10 to 20 days (we have not seen any earlier cases) there appears in the centre of the nodule a slight depression covered by a grayish, firmly adherent crust. On removal of this a small opening is revealed discharging a slightly turbid serous fluid. It is usually at this period that the nodules begin to ulcerate, starting from the centre, while an infiltration spreads into the surrounding healthy tissues.

When kept clean and in the absence of external irritation the nodule does not ulcerate, but begins to increase more or less regularly, sometimes assuming the appearance of a plaque about 4 to 5 cm. in diameter, while the skin takes on a bluish tint and its surface becomes considerably desquamated. Sometimes in the infiltrated area of the skin the papillae begin to proliferate and the surface becomes covered with numerous minute papillae. The papillae are more defined in the centre, diminishing towards the periphery, while at the edge the skin is smooth. The margins of the area of infiltration are slightly raised above the middle: between the papillae there is an accumulation of desquamating epithelium, and in some places there are small fissures discharging a slightly turbid fluid.

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[3] L. L. **Heidenreich** : Pendeh Sore (Tropical Sore). Attacks, cause, identification, etc. Publ. by Chief Milit. Med. Dept. [*St. Petersburg*, 1888. (*Review in* : *Ann. Inst. Pasteur*, **3**, 1889, 445.)]

[4] [*In the original only the initials, indicating " meat-gelatin," are given.*—C.A.H.]

In Sart sore the infiltration is continuous and individual nodules are not palpable.

Large papules are, however, comparatively rare; in most cases after 2 to 3 weeks a superficial ulcer is produced with a slightly eroded edge; the discharge from the ulcer is not copious and a crust is, therefore, easily formed; around the ulcer the infiltration area assumes a bluish-red hue and has a doughy consistence on palpation. We have never had the opportunity of seeing the lymph nodes in the course of Sart sore; in general this symptom[5] (which is, according to Raptschewsky, a complication of the sore) does not occur in the Sart sore of Tashkent.

The rate at which Sart sore spreads varies in different parts of the body. If the disease appears on the nose, the eye-lids, or the face in general, the infiltration increases far more rapidly.

p. 928 We have not observed natural healing and therefore possess no data for judging how long the sore can last; we have, however, observed several sores of more than a year's duration which had to be treated before they healed.

As regards the situations in which the sores appear, our observations confirm those of previous observers, *viz.* that the sore mainly attacks the exposed parts. But whereas in our cases the sores occurred most frequently on the face, according to Raptschewsky, Heidenreich and others, the shin and forearm were the parts most frequently affected, and the face only to a lesser degree.

As to the time of year when the incidence of the disease is highest, in Tashkent the greatest number of cases appear in January, February, March and April, and then in November and December, while there are considerably fewer cases during the summer months.

The incidence of the disease is higher among the lower classes of the population, though cases also occur among the well-to-do.

Sart sore heals with the formation of a superficial, slightly depressed, flat cicatrix; this is at first of a darker colour, but as time passes it becomes paler and remains whiter than the surrounding parts.

As regards the diagnosis, it is difficult to confuse the sore with anything else if its development is taken into consideration.

We realize that ordinary ulcers of the shin and those which frequently affect the nose might give rise to doubts. However, in the first case cleanliness and rest rapidly produce an amelioration leading to cicatrization of common ulcers, whereas Sart sore remains for weeks in the same state under similar conditions; moreover, if attention is given to the appearance of the area of infiltration—its doughy consistence, indolence, the bluish-red hue of the skin above the infiltration—its identification presents no difficulties. It is sufficient to see the sore once or twice to be able to diagnose it without error.

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[5] [*Viz., enlargement of lymph nodes due to lymphangitis*: *cf.* Heidenreich, 1888 (*abstract in Ann. Inst. Pasteur*, **3**, 1889, *p.* 445).—C.A.H.]

As regards the lesion on the nose this may at first lead to confusion with lupus, but the doughy consistence and the more diffuse character of the infiltration in the case of Sart sore, the absence of minute nodules separated from the main focus by healthy patches of skin, are sufficient for the differentiation of these disorders, apart from the difference in the rate of spreading. As *p. 929* stated above, Sart sore spreads rapidly over the whole nose, whereas in lupus the process is much slower. In the later stage of development it is impossible to confuse the two diseases since lupus destroys the cartilage and bone, whereas Sart sore never penetrates beyond the skin.

PATHOLOGICAL ANATOMY.

The earliest period at which we had occasion to examine a sore was after 2 weeks. The following are the changes observed : There are no special changes in the epidermal layer ; the Malpighian epithelial layer is already slightly altered —in the centre of the papule the interpapillary projections of the Malpighian layer are shorter than at the periphery and in places the granulation tissue penetrates through them in the form of rounded rods. The chief changes, however, occur in the dermis. The dermal papillae are permeated with the granulation elements, mostly in the form of epithelioid cells ; the proliferation of the granulation tissue proceeds mainly along the vessels. The accumulation of cells is greatest in the centre of the papule, resulting in the formation of an area of dense infiltration, while towards the periphery the islets of granulation tissue are separated from each other by areas of more or less modified connective tissue. In the deeper parts of the corium, where it passes into the subcutaneous connective tissue, are scattered accumulations of granulation elements in the form of isolated foci, which are also situated around the vessels. These deep accumulations of cells are separated from the more superficial ones by a thick layer of unaltered or slightly altered connective tissue. The blood-vessels are altered even at this early stage of development of the sore : the endothelium is swollen, inside the vessels there are accumulations of white corpuscles ; the minute arteries and veins are not infrequently narrowed to the point of disappearance of the lumen, partly owing to the accumulation of lymphoid elements around them, and partly to changes in their walls.

In the papular stage the cellular infiltration is more marked in the reticular layer of the dermis than in the papillary layer. In the course of its further proliferation the granulation tissue approaches the surface, progressively *p. 930* disrupts and destroys the Malpighian epithelial layer, raises the epidermal layer and, having destroyed the latter at some point, spreads over the surface. For this reason it is not uncommon to encounter an entire strand of epidermis as well as of the Malpighian layer in the midst of the granulation tissue, whereas at the periphery, where there is less infiltration of the cellular elements, there can be observed a considerable thickening of the epithelial layer, the interpapillary projections of the epithelium not infrequently branching and the boundary between the epithelium and the surrounding tissue not being sharply defined. This phenomenon has, however, long been noted in all kinds of chronic ulcerative processes of the skin. During the period of ulceration the changes in the vessels are more marked: the walls of the minute arteries and veins are infiltrated, the vessels in some parts being occluded. In the midst of the granulation tissue there occur free accumulations of red blood corpuscles, either still retaining their appearance or already having broken up and formed rounded or irregular yellow accumulations; such accumulations are scattered in different parts of the ulcer and also occur in the epithelial layer.

During the period of ulceration the granulation tissue undergoes further development in some parts and is transformed into connective tissue with a small number of spindle-shaped cells, this transition taking place in the more superficial layers, whereas from the deeper parts there develops a thick layer of granulation tissue.

AETIOLOGY.

The cause of Sart sore and of other similar (if not identical) "oriental sores," such as Pendeh sore, Aleppo boil, [*bouton de*] Biskra, the Elisabethpol "godovik"[6] etc., has not been firmly established up to the present.

Duclaux, Heidenreich and Chantemesse investigated the "bouton de Biskra" in 1884 and isolated in culture a micrococcus similar to (if not identical with) the golden staphylococcus [=*Staphylococcus aureus*].

p. 931 Heidenreich, who studied Pendeh sore in 1886, confirmed Duclaux's investigation, *viz.* he attributed the origin of the sore to the penetration into the skin of "micrococcus Biskra," which is apparently identical with the golden staphylococcus.

Dr. Raptschewsky, who investigated Pendeh sore after Heidenreich, obtained different results: on examining the juice of the papules he isolated a streptococcus which differs from that of erysipelas and which he regards as the causative agent.

Nicolle and Noury-Bey have carried out a bacteriological investigation of Aleppo boil (*Annales de l'Institut Pasteur*, 1897, No. 9) and have also isolated a streptococcus which they regard as the causative agent. These authors studied nine cases: in three they obtained a pure culture of streptococcus, in five cases staphylococci developed together with the streptococci, and in one case bacilli were also present. Clinically Aleppo boil runs the same course as Sart sore and Pendeh sore: at the beginning there appears a papule of the size of an acne [*pustule*] which gradually increases in size; the papule is indolent and the colour of the skin remains unchanged; by the 3rd to the 5th month the papule becomes covered with a crust under which there is an ulcerated bleeding surface; the pathological process extends further, there is an exudation of a sero-purulent fluid, and 3 to 4 months later cicatrization begins. According to NICOLLE and NOURY-BEY, the entire period of development of Aleppo boil is 11 to 12 months.

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[6] [*godovik* = (*lit.*) *annual: name for the Transcaucasian form of oriental sore, which usually persists for* 1 *year.*—C.A.H.]

However, the species of streptococci isolated by RAPTSCHEWSKY and by NICOLLE and NOURY-BEY are different. RAPTSCHEWSKY's streptococcus is distinguished by slow growth: the colonies cultivated on agar-agar at the optimum temperature (30 to 36°) become visible to the naked eye only on the 3rd or 4th day in the form of small whitish discs. On gelatin their growth is still slower; the streptococcus does not liquefy gelatin; in stab cultures growth takes place only along the course of the stab, without any signs of growth over the surface. When grown in fluid nutritive media the streptococcus forms a fine white precipitate. The streptococcus isolated by NICOLLE and NOURY-BEY is characterized by rapid growth in all kinds of media: the development of the colony can be noticed even after 24 hours; when growing in broth the streptococcus produces a golden-yellow colour.

From the foregoing it is obvious that there is a complete difference of opinion regarding the aetiology of "oriental sore." Before turning to the results of our own research, we shall give an account of the method of investigation. *p. 932*

If the patient was in hospital, the sore was dressed for several days with warm boric acid compresses; then the papule was washed with alcohol and ether, after which it was excised and removed with instruments boiled in a solution of soda. A scraping was then immediately taken from its deep bleeding surface with a sterilized knife. By means of a platinum loop passed through a flame this scraping was transferred to gelatin or agar-agar which was poured out into Petri dishes; or the superficial layers of the sore were removed with a sharp spoon, while with a second spoon scrapings were made from the deeper parts and were used for making smears on slides and for inoculation. The excised portions of the papules, and sometimes of the ulcers, intended for an anatomico-pathological investigation were first hardened in 95 per cent. alcohol and then embedded in celloidin for the preparation of sections. The very first cases studied by us produced unexpected results: streptococci were not obtained in cultures but in their stead there developed a small number of yellow and white staphylococcus colonies and sarcinae, the number of bacteria being so insignificant that in the second and third cultures only a few isolated colonies developed, in view of which we made only one culture in subsequent cases. Moreover, in smears from the juice of the papules microorganisms were either absent or only solitary cocci were encountered.

From the end of 1895 we began to examine the juice of papules and sores in which no inflammatory phenomena were manifested, in hanging drops, and were astonished by the presence of numerous motile corpuscles, some round, some irregular, while some of them possessed pseudopodia.[7] Since that time and up to the present we have found the same structures every time we have examined the juice and scrapings from the sores.

The younger the papule the greater was the number of these corpuscles, whereas only a few of them were present in scrapings from the depth of the older sores. At the beginning, when we dried and fixed the smear directly over the flame, according to the method usually adopted, the examination of the smears gave negative results. Recently, however, when we proceeded *p. 933* to fix the smears with a mixture of absolute alcohol and ether, staining with Loeffler's solution revealed the same corpuscles which had been observed in the hanging drop. The size of these structures varies from $\frac{1}{2}\mu$ to 2μ, occasionally reaching 3μ, but in most cases their dimensions are from $1\frac{1}{2}$ to 2μ. These corpuscles frequently have a fine process as long as, or sometimes longer than the diameter of the corpuscle; at the end of the process there is not infrequently a small globular thickening;[8] sometimes several—two and three—of these processes are observed. The corpuscles described are colourless: they are sometimes homogeneous, or they appear to have a nucleus in the centre or at the periphery, while in some of them vacuoles can be seen.[9] Moreover, in the hanging drop are observed minute dark structures of a round shape with one or several fine processes; the latter structures are very motile.[10]

The shape of the corpuscles is sometimes spherical and sometimes fusiform. Occasionally a change in their shape could be observed—an oval would change into a sphere, then into an irregularly-shaped body and afterwards again become oval.[11] In two cases spheres were observed measuring 4 to 5μ, having a double-contoured membrane and densely packed with round corpuscles. One such sphere was seen to be half empty, while in the other half the round corpuscles were also disposed outside the membrane.[12]

If a hanging drop preparation was left in a thermostat it showed considerable changes after 24 hours: the larger round bodies disappeared and broke up, while the number of the above-mentioned minute structures with fine processes increased.[13] If the preparation was pure, all the structures disappeared after

[7] [*It is possible that some of these " corpuscles " may have been blood platelets and that the motility refers to Brownian movement.*—C.A.H.]

[8] [*The appearance of the " corpuscles " described here would suggest that in some of the parasites only the nucleus and rod-shaped kinetoplast were visible, a not infrequent occurrence in poorly fixed tissues.*—C.A.H.]

[9] [*These cases probably refer to the whole parasite.*—C.A.H.]

[10] [*V. supra: footnote* 7.]

[11] [*The apparent change of shape can be accounted for by the different views of the parasite, obtained in the course of its slow revolution.*—C.A.H.]

[12] [*These " spheres " represent detached fragments of the cytoplasm of the host-cells. They have been described by other authors, some of whom have regarded them as representing the parasite itself, while the true parasites were mistaken for its " spores "* (CUNNINGHAM, 1885; FIRTH, 1891; and ROSS, 1903: *the last in the case of kala-azar*).—C.A.H.]

[13] [*V. supra: footnote* 7.]

2 or 3 days, whereas in the case of contamination with bacteria the latter, which were chiefly cocci, developed.

On examining sections of preparations fixed with 95 per cent. alcohol and stained, according to RAPTSCHEWSKY's directions, with Loeffler's solution we never found any streptococci, but there were masses of what at first appeared to be cocci, some round, but most of them oval, arranged in clumps which were frequently spherical.[14] These cocci were in most cases packed in the protoplasm of the lymphoid and epithelioid cells.[15] In some cases after inoculation from excised papules the plates remained sterile, although an examination of the sections revealed a large accumulation of the cocci in question, while in *p. 934* the hanging drop the above-mentioned corpuscles were always observed in large numbers.

At the end of 1897 we began to employ for fixation Zenker's fluid, the composition of which is as follows:—Aq. destillatae 100·0, corrosive sublimate 5·0, potassium bichromate 2·5, sodium sulphate 1·0, acetic acid 5·0.

A freshly excised piece was dropped into this fluid and left there for 12 to 24 hours, after which it was washed for 24 hours in water and then transferred to 60 to 70 per cent. alcohol, absolute alcohol, absolute alcohol + ether, and embedded in celloidin.

After fixation with this fluid we succeeded in discovering in sections masses of corpuscles of the same size and shape as we had observed in the hanging drop.

The younger the papule of Sart sore the greater the number of these corpuscles; the older the papule, or if in the period of ulceration, the fewer these corpuscles; and finally, in old papules with extensive ulceration or in those treated by cauterization, we found them with difficulty and even then in an altered state.

The fresh papule presents the following picture: these corpuscles are absent in the epidermoid and epithelial layers, and are rare in the papillae; the parasites, in most cases enclosed within cells, only make their appearance where the infiltration rises from the deeper layers of the skin to the papillae; the parasites are most numerous in the deeper parts where the accumulation of granulation cells is the greatest. The cells are literally packed with them to such an extent that the limits of the individual parasites cannot be seen, and they appear as one continuous mass in which only their nuclei, stained deeply with Loeffler's solution, are distinctly visible. This is the reason why the earlier preparations produced the impression that these accumulations consisted of cocci. However, deeper down, towards the subcutaneous connective tissue, the accumulations of parasites become less abundant and it is here that they can be observed *p. 936* individually. They proved to be mostly round corpuscles (though some are oval and spindle shaped) with a very faintly stained protoplasm and a sharply stained nucleus situated at the periphery. This nucleus is either round or elongated in shape, while sickle-shaped nuclei are also not uncommon.

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[14] [*When the nuclei only of the parasites are visible, an appearance of masses of cocci is produced. However, as will be seen below, the author was fully aware of the true nature of these " cocci."*—C.A.H.]

[15] [*This is the first correct interpretation of the nature of the parasitized host-cells.*—C.A.H.]

As mentioned, these parasites are in most cases situated within cells, the nucleus [*of which*] is shifted to the periphery, stains badly and is shrivelled, or sometimes destroyed, a cluster of parasites being seen in place of the cell. Accumulations of parasites also occur outside the cells. In such cases there are encountered spheres filled with round corpuscles with a feebly stained protoplasm and a nucleus at the periphery.

Still deeper, where there is no infiltration with the lymphoid elements, in the fissures between bundles of connective tissue and in the perivascular spaces, there can be seen rows and small clumps of the same parasitic cellular structures.

The size of the parasites is in most cases about 1μ, sometimes larger, but rarely smaller. Their nuclei vary in dimensions; sometimes they occupy a considerable part of the whole body, and not infrequently there can be seen a fine process running from the nucleus to the opposite side of the body, the process bearing a small globular thickening.[16]

On examining a papule, in which a small ulceration covered with a crust has already been formed, it is seen that the cellular infiltration, having reached the surface of the epithelial layer, has destroyed it and spread over the surface. The infiltration penetrates into the depth and spreads widely, while the parasites together with the granulation elements break their way outwards, though they are considerably less numerous on the surface than in the deeper parts.

On the other hand, the accumulations of lymphoid elements scattered in the subcutaneous connective tissue also contain smaller numbers of the parasites.

Amongst the accumulations of blood found at the bottom of the ulcer are seen considerable numbers of parasites which are occasionally situated within the red blood corpuscles.[17]

Several times, on examining the juice of the papules in a hanging drop, we *p. 937* have observed the parasites inside the red blood corpuscles, the parasite changing its position and shape. In sections the greatest accumulation of parasites occurs around the vessels where, as already stated, the infiltration is also greatest.

The oldest papule examined by us was about 1 year old. This case had been treated by repeated applications of tincture of iodine. In this instance most of the granulation tissue had passed into the connective tissue and only small accumulations of lymphoid elements were encountered in different parts of the section. The parasites could be detected with difficulty and had undergone alterations: they stained uniformly and most of them had bud-like outgrowths.

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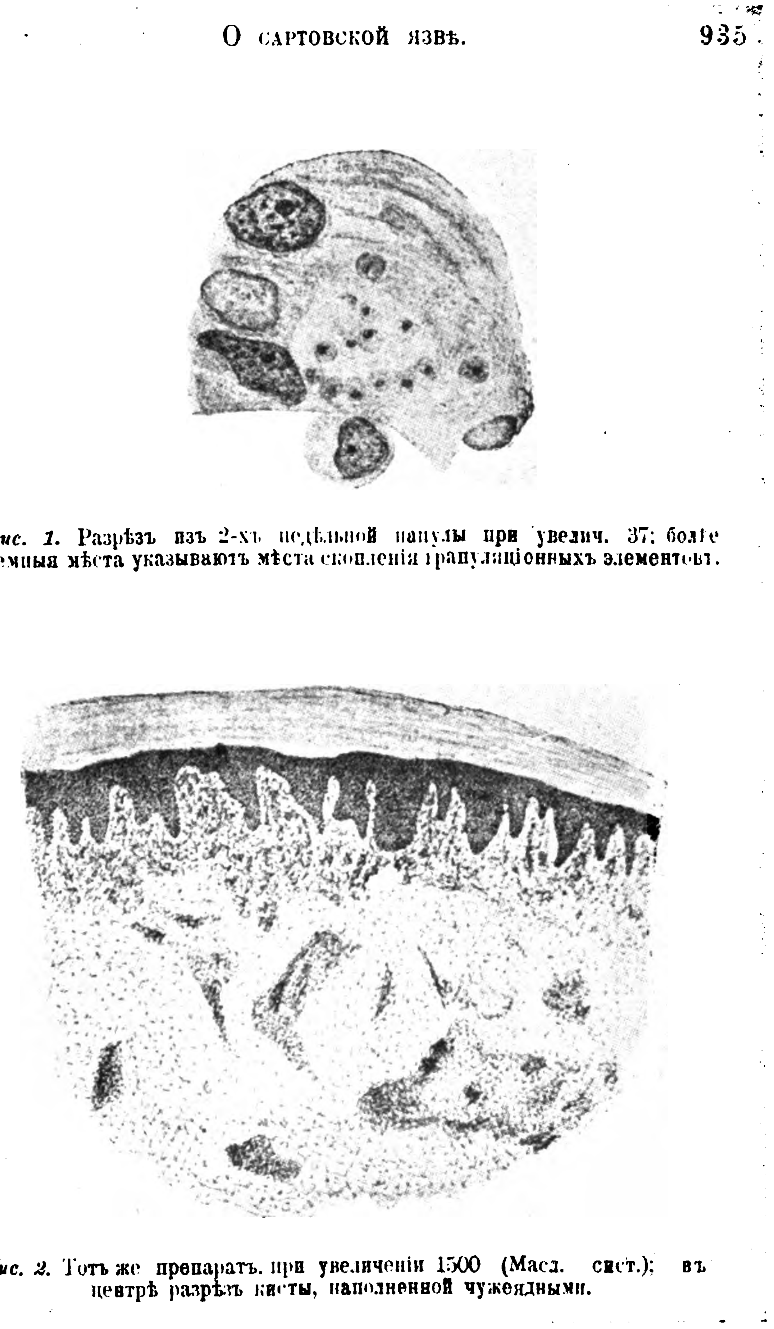
[16] [*This description evidently refers to the whole parasite in which the nucleus and elongated kinetoplast* ("*process*") *were seen.*—C.A.H.]

[17] [*Misinterpretation of superimposed position of the parasites. The same error was committed by a number of authors in the case of* Leishmania donovani (LAVERAN, 1903; LAVERAN & MESNIL, 1903; LEISHMAN, 1903).—C.A.H.]



О сартовской язвѣ. 935

Рис. 1. Разрѣзъ изъ 2-хъ недѣльной папулы при увелич. 37; болѣе темныя мѣста указываютъ мѣста скопленія грануляціонныхъ элементовъ.

Рис. 2. Тотъ же препаратъ. при увеличеніи 1500 (Масл. сист.); въ центрѣ разрѣзъ кисты, наполненной чужеядными.

FACSIMILE OF PAGE 935 IN BOROVSKY'S MEMOIR.

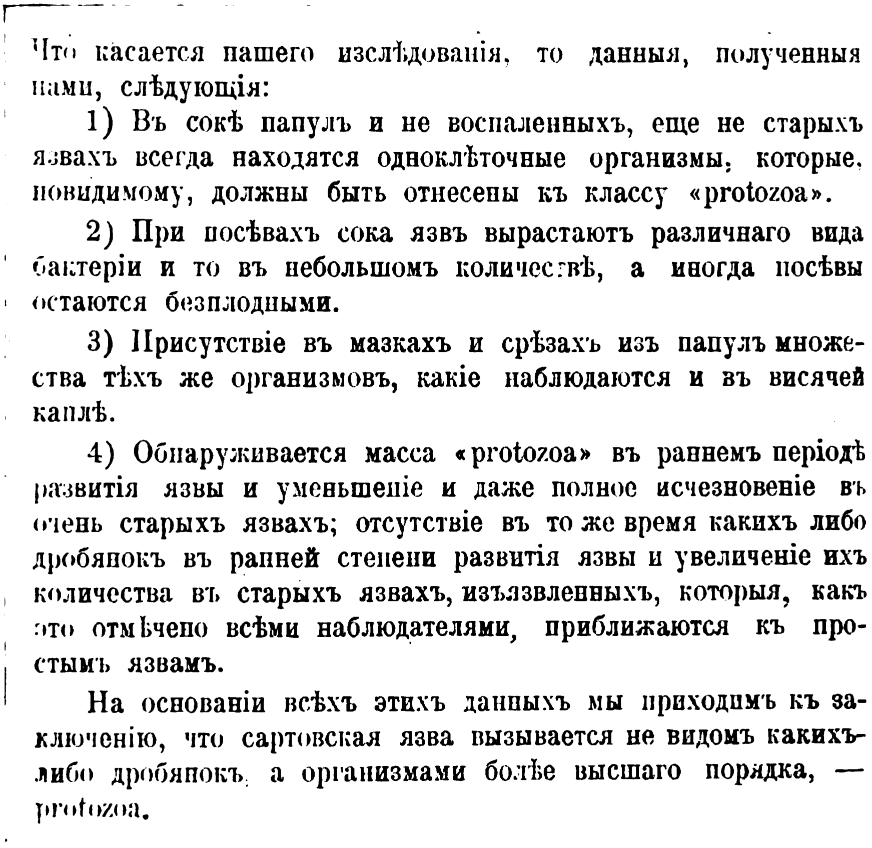
Legend to Figures.

(*Translated from the Russian.*)

FIG. 1.—Section from papule 2 weeks old, at a magnification × 37 : the darker places indicate the areas of accumulation of granulation elements.

FIG. 2.—The same preparation at a magnification × 1,500 (oil immersion) : in the centre is a section of a cyst filled with parasites.

[*As in the original article, the arrangement of the description is reversed, Fig.* 1 (*top*) *bearing the legend of Fig.* 2 (*bottom*), *and vice-versa.*—C.A.H.]



Что касается нашего изслѣдованія, то данныя, полученныя нами, слѣдующія:

1) Въ сокѣ папулъ и не воспаленныхъ, еще не старыхъ язвахъ всегда находятся одноклѣточные организмы, которые, повидимому, должны быть отнесены къ классу «protozoa».

2) При посѣвахъ сока язвъ вырастаютъ различнаго вида бактеріи и то въ небольшомъ количествѣ, а иногда посѣвы остаются безплодными.

3) Присутствіе въ мазкахъ и срѣзахъ изъ папулъ множества тѣхъ же организмовъ, какіе наблюдаются и въ висячей каплѣ.

4) Обнаруживается масса «protozoa» въ раннемъ періодѣ развитія язвы и уменьшеніе и даже полное исчезновеніе въ очень старыхъ язвахъ; отсутствіе въ то же время какихъ либо дробянокъ въ ранней степени развитія язвы и увеличеніе ихъ количества въ старыхъ язвахъ, изъязвленныхъ, которыя, какъ это отмѣчено всѣми наблюдателями, приближаются къ простымъ язвамъ.

На основаніи всѣхъ этихъ данныхъ мы приходимъ къ заключенію, что сартовская язва вызывается не видомъ какихъ-либо дробянокъ, а организмами болѣе высшаго порядка, — protozoa.

FACSIMILE OF PART OF PAGE 939 IN BOROVSKY'S MEMOIR.

General conclusions, corresponding to pp. 88-89 of the Translation.

To the above it may be added that no schizomycetes could be detected in the non-ulcerating papules by staining.

The parasites described by us stain with Loeffler's solution, the sections being kept in the stain from 2 to 24 hours. Good staining can also be obtained with a saturated aqueous solution of safranin, but the parasites do not stain by Gram's method. We also tried to stain sections by Romanowsky's method (a mixture of eosin and methylene blue) and by the method of Sanfelice, as recommended by the latter for blastomycetes, but though they stained the staining was not sharp. The best method, therefore, is to stain with Loeffler's methylene blue solution followed by rinsing in water and decolorizing in alcohol, but the differentiation should not be carried too far: the same refers to the staining with saturated aqueous solution of safranin.

We failed to obtain cultures of the structures described: inoculations were made into the fluid obtained by puncture of a hydrocele, on agar-agar mixed with ascitic fluid, and in sterile grape juice.

Owing to the peripheral position of the nucleus and to the presence of processes like flagella,[18] we are inclined to refer the parasites described by us to the class of protozoa. Their multiplication apparently takes place both by means of direct division and by budding. We have observed corpuscles in which a short round outgrowth or bud is formed on the periphery, therefore multiplication by budding takes place,[19] though round corpuscles in which a fine process with *p* 938 a thickening at the end is given off from the nucleus occurred more frequently.[20] There also occurred corpuscles with two nuclei situated at opposite ends of the body. As the result of slow multiplication there may thus be produced several separate corpuscles enclosed in a common membrane, as was observed by us[21]; whereas in the course of rapid multiplication the division of the nucleus is followed by fission of the protoplasm and separate individuals are produced. It is difficult, of course, to form an exact idea of the method of multiplication from a dead preparation, and not from a pure culture, therefore the account given above represents a personal impression.

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[18] [*Vide infra: footnote* 20.]

[19] [*It is not improbable that the budding forms represent some yeast-like organism which may be present in ulcerating sores and bear some resemblance to* Leishman-Donovan *bodies when stained* (*cf.* WENYON, 1926, *p.* 428). *The latter interpretation receives support from the fact that a yeast was actually cultivated by the author from sores* (*cf. p.* 88).—C.A.H.]

[20] [*The presence of a "process" in the parasite is mentioned four times in the text* (*cf. footnotes*: 8, *p.* 84; 16, *p.* 86; 18, *supra*). *According to* BOROVSKY, *it arises from the nucleus, runs to the opposite side of the body and is provided with a "globular thickening" at the end* (*there is no indication as to whether it is at the proximal or distal end of the "process"*). *It is obvious that* BOROVSKY *must have seen the kinetoplast, either alone or together with the rhizoplast. In the former case the whole "process" would be equivalent to the kinetoplast, in the latter case the "globular thickening" alone would represent this structure, the "process" itself being the rhizoplast.* BOROVSKY *himself likened the "process" to a "flagellum," but the indications in the text suggesting that in some cases he must have seen only the nucleus of the parasite with the attached "process," coupled with the fact that the kinetoplast always stains deeply and is, therefore, more commonly seen in preparations of the* Leishman-Donovan *bodies than the rhizoplast, are strong arguments in favour of regarding* BOROVSKY'S *"process" as the kinetoplast. This is the view held by* PAWLOWSKY (1927, 1931); *and* Dr. C. M. WENYON, *whom I have consulted on this matter, is of the same opinion.*—C.A.H.]

[21] [*A condition interpreted by some authors as multiple division.*—C.A.H.]

In old Sart sores the parasites described are very scanty and they are, moreover, modified—thus there occur round corpuscles similar to those described above in size, but either uniformly stained or in the form of a transparent vesicle only the outline of which is visible. Even when those with nuclei are encountered, the nucleus is considerably smaller than usual and not so deeply stained as in the case of preparations from young papules.

In addition to what has been said above, it must be stated that, up to the present, inoculations from the Sart sores examined were made in Petri dishes and colonies were obtained of staphylococci (most frequently) and sarcinae; moreover, in three cases there developed very minute oval cocci which did not liquefy gelatin and, when examined in the living condition, were mostly arranged in pairs, in the form of diplococci; in one case there appeared in a Petri dish with agar-agar five colonies of microc.[*occus*] tetragenus; and in another case there developed amongst other colonies pink yeasts, while in two cases the plates remained sterile. The total number of cases examined by us exceeded twenty, nine of which were still in the form of papules.

Of course, we cannot yet extend the results obtained from the investigation of Sart sore to other similar diseases of the skin, such as Pendeh sore, Aleppo boil, [*bouton de*] Biskra, Elisabethpol " godovik "[22], etc., but would suggest the desirability of verifying their nature from the point of view put forward by us. The desirability of this verification is based on the following facts. In his study of Pendeh sore, RAPTSCHEWSKY makes the following statement: " in *p. 939* spite of repeated investigations, the result of bacterioscopic examinations of the ' lymphangitic ' nodules[23] in cases of Pendeh sore remained negative. It was impossible to detect any microorganisms in the juice mixed with blood obtained from incised nodules, either microscopically or by means of cultures."

However, in another place RAPTSCHEWSKY mentions that under the influence of irritation such a " lymphangitic " nodule may suppurate, open and then heal, like an ordinary abscess; and, further, that these complications in the form of lymphangitis occur in the case of sores which are contaminated or irritated, and in which there is a retention of pus under the crust. If that is the case, why are there no microbes in the " lymphangitic " nodules ? However that may be, it is impossible to decide anything *a priori*.

As regards our own investigation, the data obtained by us are as follows:—

(1) In the juice of papules and in sores which are not yet old and have not ulcerated, there are always present unicellular organisms which should apparently be referred to the class " protozoa."

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[22] [*Cf. Footnote* 6, *on p.* 82.]

[23] [*These are evidently the lymph nodes affected by lymphangitis.*—C.A.H.]

(2) In cultures of the juice from sores there grow various kinds of bacteria, though in small numbers, but sometimes the cultures remain sterile.

(3) In smears and sections of papules there are present large numbers of the same organisms which are observed in the hanging drop.

(4) Masses of " protozoa " are encountered in the early period of development of the sore, diminishing and even disappearing completely in very old sores. At the same time bacteria of any kind are absent in the early stages of development of the sore, but they occur in increasing numbers in old ulcerating sores, which, as has been noted by most observers, approximate to ordinary ulcers.

From all these data we arrive at the conclusion that Sart sore is not caused by any kind of bacteria, but by organisms of a higher order, *viz.* protozoa.

As regards the method of infection, we are inclined to think that the infection does not penetrate into the skin directly, but is conveyed either from the intestinal tract or from the respiratory apparatus through the blood. *p. 940*

The fact that exposed parts of the body are affected by preference can be explained by the greater susceptibility of these parts to traumata and to the appearance of minute capillary haemorrhages in which the accidentally transferred parasites find a suitable material [= *medium*] for development. Owing to the low toxicity of the products of metabolism of these parasites the phagocytes overcome them with comparative ease, and although many of the phagocytes perish, they appear in ever increasing numbers and finally destroy the parasites. That protozoa can find their way into the respiratory tracts has been proved experimentally. Thus, GRASSI and FELETTI demonstrated the presence of an extremely minute amoeba in the nasal cavities of pigeons which remained for two nights in a marshy locality at an altitude of 2 metres above the level of the ground, while 9 days later the same amoebae were found in the blood of the pigeons (LAVERAN et BLANCHARD, *Hématozoaires du Paludisme*). Infection with marsh fevers also takes place through the respiratory tract. Infection through the intestinal tract is possible through water and, it may be, through contaminated food.

As regards water used for washing and bathing, the transmission of infection through this medium is very doubtful, since, in spite of the fact that during the summer heat the entire Russian population of Tashkent bathes in " aryk " water[24], cases of this disease are very rare in summer. According to our observations, cases occur more frequently during the winter and spring months of the year. The last circumstance also shows that the rôle of dust in the spread of the disease is insignificant (if indeed it serves as a vector of the infection at all), for during the said time of the year the rainfall in this locality is very heavy.

TREATMENT.

In Tashkent the most commonly used remedy for the treatment of Sart sore is pure lactic acid, which is employed either in an ointment or in a layer of *p. 941* cotton wool impregnated with it and applied to the sore, where it is left for 24 hours. The latter method is more reliable ; when it is used the healthy skin around the sore is covered with collodion or an adhesive plaster. After 24 hours the dressing is removed and in place of the previous infiltration a scab is formed under which is a clean ulcerated surface, which is usually treated as an ordinary ulcer.

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[24] " Aryki " [*pl.*] are shallow canals by which water is conveyed for the irrigation of gardens, kitchen-gardens and fields [*in Turkestan*].

When the ulcer is cauterized successfully in this manner it heals in the course of 2 to 4 weeks. We have also applied the sublimate ointment recommended by Dr. TEKUTIEV with satisfactory results.

However, in some cases the infiltration re-appeared after cauterization and subsequent cicatrization ; in these cases we scraped it thoroughly with a sharp spoon. Scraping was also practised in cases where the eyelids were affected and cauterization could not be employed. A thorough scraping was always followed by healing.

When the papules were excised right down to the subcutaneous connective tissue, we inserted a suture which in most cases resulted in complete healing *per primam intentionem*, though sometimes under the cicatrices a fresh lesion would occur, necessitating either cauterization or scraping.

APPENDIX III.

K. SHULGIN (1902) : ON THE TRANSMISSION OF ORIENTAL SORE.

It has already been mentioned (p. 71) that K. SHULGIN, who was BOROVSKY'S contemporary at the Tashkent Military Hospital, fully confirmed his colleague's observations on the aetiology of oriental sore. However, SHULGIN'S real claim for a place in the history of tropical medicine rests on the views he expressed regarding the transmission of this disease, for he was actually the first to suggest, in 1902, that the vector was a blood-sucking insect. The part played by SHULGIN in enunciating this hypothesis is practically unknown to anyone, either in his own country or outside it. One of the reasons for this is probably the fact that the journal in which SHULGIN'S paper was published is just as inaccessible as the one in which BOROVSKY'S memoir appeared.

The only reference to SHULGIN'S observations which I have been able to discover is a statement occurring in LAVERAN'S monograph that " Shulgin croyait que les moustiques étaient les agents de transmission du bouton d'Orient " (LAVERAN, 1917, p. 437*).

It is not indicated, however, that this was actually the first suggestion of the rôle of blood-sucking insects in the transmission of this disease. On the contrary, the preceding paragraph—according to which " dès 1875, SÉRIZIAT déclarait avoir vu des boutons de Biskra ayant incontestablement pour origine des piqûres de moustiques " (*loc. cit.*, p. 437)—might be construed as establishing the priority of SÉRIZIAT, but from an extract of this author's writings appearing

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*LAVERAN, A. (1917). *Leishmanioses*. (Paris : Masson et Cie.)

elsewhere in the monograph (*loc. cit.*, pp. 429-430) it is obvious that SÉRIZIAT merely asserted that the slightest lesion in the skin may serve as the starting point of oriental sore, and that he himself had seen sores originating at the site of a mosquito-bite. He did not, therefore, imply that the disease was disseminated by the mosquito, but that this insect was one of the agents, including mechanical ones, capable of impairing the intactness of the skin and thereby exposing it to infection.

SHULGIN's paper—" The question of the aetiology of Pendeh sore "—was written in Russian and published in the journal ***Russkij Vrač*** [= The Russian Physician], 1902, Nos. 32 and 33, pp. 1150 and 1180. These issues are unobtainable in this country, and I am indebted to the late Prof. G. W. EPSTEIN, of Moscow, for a typewritten ***verbatim*** copy of SHULGIN's article, from which I have translated the most interesting passages relating to the transmission of oriental sore.

After discussing the views of other Russian observers, who believed that the causative organism was found in water, or in the soil, and was disseminated by dust through the air, SHULGIN proceeds as follows :—

> " However, I am inclined to consider that the mode of penetration of the infective agent into the body is the same as that recognized at present for marsh fever, *i.e.*, that it has an intermediate host—a mosquito or some other nocturnal biting insect."

The author then goes on to substantiate his contention :—

> " In eight cases I succeeded in observing the very earliest phase of the disease, the primary papule, [at a period] when it was even impossible to identify it with certainty, but from which a typical Pendeh sore developed later. It then appeared in the form of a reddish, raised, compact spot, as large as a lentil. In the middle there was always a darker point, similar to that in the centre of a mosquito or flea bite. Intelligent persons in whom I observed such primary papules testified that they had actually been bitten in these places by something on a previous evening. . . . Moreover, on the assumption that the infection is spread by insects, it is easy to explain why the sore appears only during a certain period of the year. In all the localities where the disease is endemic cases are observed at the end of summer and at the beginning of autumn exclusively. . . . This can be fully accounted for on the basis of the mosquito theory, for mosquitos appear in large numbers in July. The time between their appearance and the occurrence of the first cases of the disease is taken up by the infection [of the insects], the development of the microorganism in them, its inoculation [to man], and the incubation period. In October the mosquitos disappear and no fresh cases occur while the old sores sometimes persist for 2 years. . . . "

SHULGIN also quotes the following observation in support of his views: In a certain locality of Turkestan the officers and men of the garrison shared the same barracks, but cases of oriental sore occurred among the privates exclusively. According to the author, this was due to the fact that only the officers slept under mosquito-nets and were, therefore, protected from the bites of the insects.

Lastly, SHULGIN notes that the sores appear most frequently on those parts of the body which are covered in the daytime, but may be exposed in the night (arms, legs).

In conclusion, the author makes the following statement : " As I said at the beginning, the insect transmitting the infection must be nocturnal, and now I more definitely attribute it to the mosquitos."

In the foregoing passages the case is presented in such a lucid manner and the arguments brought forward are so convincing that no special comments are required. It will be noted how near SHULGIN was to the correct solution of the nature of the vector of oriental sore, for all the observations and arguments adduced by him in support of his hypothesis regarding the transmission of the infection by mosquitos are equally applicable to the sandflies, which, in Turkestan, usually make their appearance in the middle of June and disappear towards the beginning of October, while the similarity of the feeding habits of both these groups of insects is well known.

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THE ENDOGENOUS DEVELOPMENT OF THE COCCIDIA OF THE FERRET, AND THE HISTOPATHOLOGICAL REACTION OF THE INFECTED INTESTINAL VILLI

BY

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(*Received for publication* 1 *February*, 1935)

The coccidia of the ferret were first described about eight years ago (Hoare, 1927). It was shown that this animal harboured three distinct species, *Isospora laidlawi*, *Eimeria ictidea* and *E. furonis*, and the account given of the exogenous stages of development of these parasites provided all the data of systematic value.*

In the case of the two species of *Eimeria*, experimental infections were produced in two ferrets by feeding them on large numbers of mature oöcysts. These were obtained from the faeces of naturally infected animals and were preserved in a solution of chromic acid, in which their sporulation took place. Before proceeding with the experiments it was established by daily examination of the stools for one month that the two ferrets in question were free of coccidial infection.

After the infective meal, the ferrets were kept under daily observation till oöcysts first appeared in their faeces ; they were then sacrificed and the entire intestines were fixed in an alcoholic solution of Bouin's picro-formol and preserved in 70 per cent. alcohol.

The present account of the endogenous development of *Eimeria ictidea* and *E. furonis* is based mainly on sections of the intestines of the experimental ferrets, though material obtained from ferrets with natural ' pure ' infections was also used to some extent.†

The sections were stained with Mayer's acid haemalum and counterstained with aqueous eosin.

As regards the third coccidium, *Isospora laidlawi*, it was not possible to study its development satisfactorily owing to the extreme scantiness of the infection in the ferrets examined by me.

The endogenous cycle of both species of *Eimeria* follows the conventional lines, and would not warrant a detailed description if it were not for the fact

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*Since in some publications I am credited with describing the coccidia of an '*African*' ferret, I take this opportunity to point out that both the polecat, *Mustela* (*Putorius*) *putorius*, and its domesticated variety, the ferret, *M.* (*P.*) *p.* var. *furo*, are limited in their geographical distribution to Europe. As stated in my earlier paper, the ferrets which served for the investigation were all obtained in England.

†Some of this material was kindly placed at my disposal by Dr. P. P. Laidlaw, F.R.S., to whom my thanks are due.

that some of the stages provide differential diagnostic characters which supplement those already noted in the exogenous stages of development of these coccidia (Hoare, 1927). Moreover, further interest is added by the fact that *E. ictidea* provokes a peculiar histological reaction on the part of the infected intestinal villi of its host.

EIMERIA FURONIS Hoare, 1927

The development of *E. furonis* takes place in the epithelium of the small intestine and rectum of the ferret. The distribution of the parasites in the mucous membrane is very irregular : in some sections large areas are seen to be densely packed with them, while others are quite free from infection. In the small intestine the parasites may invade the entire length of the villi as far as the opening to Lieberkühn's crypts, but they are mainly concentrated in the apical portion, their numbers rapidly diminishing towards the crypts. In the rectum the coccidia are restricted to the epithelium of the free surface of the mucous membrane, viz., to the ridges between the openings of the glands of Lieberkühn.

Within the epithelial cells the parasites occupy a position between the nucleus and the lumen of the gut. The infections observed were fairly heavy ones, the host-cells in the more densely invaded portions of the epithelium usually harbouring several parasites, the number present being limited only by the accommodation available.

Though the experimentally infected ferret received a single dose of mature oöcysts of *E. furonis*, it would seem that their endogenous development did not proceed *pari passu*, since various stages of development up to the formation of oöcysts were well represented.

Similar conditions were observed in the intestines of the naturally infected ferrets, the only difference being in the relative proportion of the various forms of the parasite present. Thus, in the experimental ferret the stages of schizogony were predominant, while in the naturally infected animals the sexual forms were more numerous. The various stages are indiscriminately mixed and do not exhibit an arrangement into ' age-groups,' as is the case with *E. ictidea*.

The earliest stages (as seen in the experimental ferret) were spherical forms, about 3–4μ in diameter, with a relatively bulky nucleus consisting of a deeply staining karyosome and an unstained outer area (fig. A, 1). This form obviously represents the trophozoite or undivided young schizont. By successive nuclear divisions and growth this form develops into the ripe schizont (fig. A, 2, 3, 4), from the surface of which the merozoites are budded off, leaving a cytoplasmic residue (fig. A, 5). The merozoites produced by these schizonts are stumpy, sausage-shaped bodies measuring about 3–4μ in length and 2μ in breadth (fig. A, 6).

In addition to the type of schizogony just described, another was observed which results in the production of a different form of merozoites. These are elongated curved bodies, measuring about 6μ by 1·3μ, with one end of the body rounded and the other drawn out. A compact nucleus is situated near the blunt extremity (fig. A, 7, 8).

Schizogony of the second type was encountered almost exclusively in the naturally infected ferrets, in which the sexual forms of the parasite were predominant. In these cases small and medium-sized ovoid forms (fig. A, 9, 10), evidently representing young gametocytes, are present in large numbers. The elongated merozoites (fig. A, 8) can easily be linked up through these forms with the fully developed gametocytes (fig. A, 11, 12). It would thus appear that the first type of schizogony (fig. A, 1–6) represents the asexual reproductive cycle of *E. furonis*, while the second type results in the formation of sexually differentiated merozoites or gamonts which give rise to the gametocytes.

The macrogametocyte (or macrogamete) is spherical, about 8μ in diameter, and contains darkly staining globular inclusions of reserve material (fig. A, 11). The male gametocytes and gametes (fig. A, 12, 13) present no special peculiarities. When examined fresh the oöcyst of *E. furonis* measures on the average about

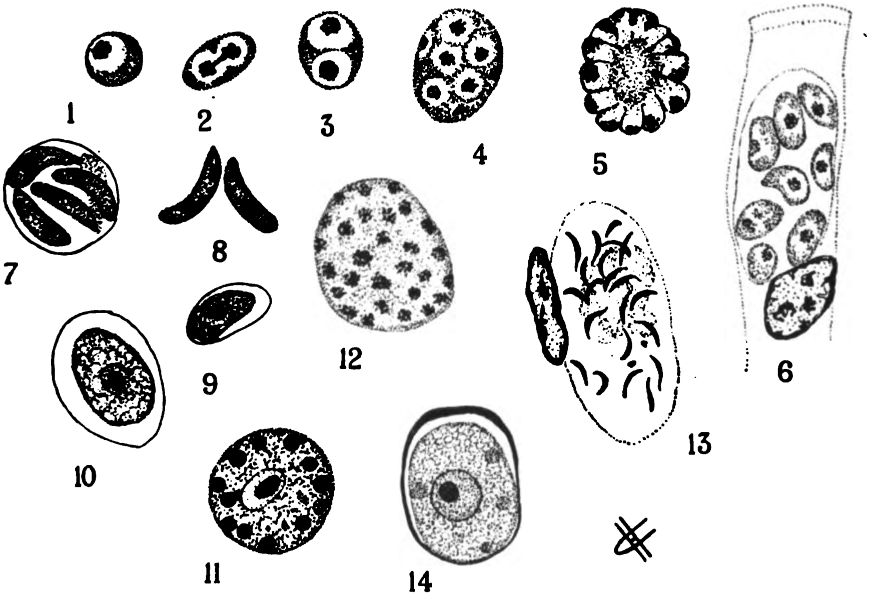

FIG. A. *Eimeria furonis*. 1-7.—Schizogony: 1.—Young schizont or trophozoite; 2, 3.—First nuclear division; 4.—Later stage of schizogony; 5.—Merozoites budding off from the surface of schizont; 6.—Schizogony completed: host-cell vacuole containing fully developed merozoites of agametogenous generation; 7.—Stage equivalent to 6, but producing merozoites of gametogenous generation. 8.—Merozoites of gametogenous generation free in lumen of gut. 9, 10.—Young gametocytes. 11.—Macro-gametocyte, or gamete, with globular inclusions. 12.—Microgametocyte in process of gamete-formation. 13.—Fully developed microgametes and gametocytic residue in vacuole of host-cell. 14.—Oöcyst with zygote (wall crumpled owing to fixation). (All the stages depicted, except in 8, were intracellular. Drawn with the aid of a camera lucida at × 2,000.)

12·8μ by 12·0μ, the zygote being about 9·6μ in diameter. In sections, as is to be expected, the dimensions are reduced, while the oöcyst wall is usually somewhat crumpled as the result of fixation (fig. A, 14).

The infection with *E. furonis* exerts no harmful effect upon the host, while the mucuous membrane of the intestine does not exhibit any special histological reaction to the parasitic invasion. The only effect observed is an enlargement and irregular arrangement of the epithelial cells in the most heavily infected parts of the mucous membrane and the denudation of some areas due to the shedding of infected epithelium, as is usual in coccidiosis.

EIMERIA ICTIDEA Hoare, 1927

The endogenous development of *E. ictidea* proceeds in the epithelium of the small intestine of the ferret. The infections studied were extremely heavy, but the distribution of the parasites in the mucous membrane was ' patchy,' the villi in some regions being packed with them, while in others they were entirely free from infection.

Unlike *E. furonis*, *E. ictidea* invades only the free portion of the villi, especially the tip, the epithelial cells never harbouring more than one parasite, although in the early stages of development, when the parasite is as small as the forms of *E. furonis*, there is room for more than one. However, as the parasite grows it gradually fills up the entire available space in the host-cell, the nucleus of which is shifted towards the base of the cell. This early adaptation obviously provides for the future requirements of the growing parasite.

The development of *E. ictidea* appears to proceed in a more regular manner than that of *E. furonis*, for the great majority of forms observed in the experimentally infected ferret were represented by the sexually differentiated stages, ranging from the young gametocytes to the fully developed gametes and oöcysts. The only indubitable stage of schizogony seen was the final one with fully formed merozoites. It would thus appear that all the sporozoites of *E. ictidea* introduced in a single dose develop more or less simultaneously, and at the same rate. This is one of the reasons why certain stages of development, viz., those of early schizogony, were not observed.

Another characteristic feature of *E. ictidea* is the arrangement of the parasites in ' age-groups ' or ' colonies.' While in *E. furonis* all stages are found freely intermingled in the epithelium, in *E. ictidea* forms belonging to the same stage are grouped together. In some cases a villus is occupied only by a colony of fully developed schizonts, or of mature male and female gametocytes, or of young forms, etc., while in other cases a group of forms representing one stage may be contiguous to an independent group of another stage.

The youngest forms observed were merozoites (fig. B, 2) lying free in the lumen of the gut in the neighbourhood of groups of fully segmented intracellular schizonts (fig. B, 1) from which they had arisen. The merozoites are elongated vermicular bodies measuring about 11μ by 1μ, with one extremity rounded and the other drawn out to a point. The compact nucleus is situated near the rounded extremity. After penetrating into the host-cell, the merozoites shorten (fig. B, 3, 4), become rounded and grow in size (fig. B, 5, 6). These forms measure from 3μ to 4μ in length or diameter. They evidently represent

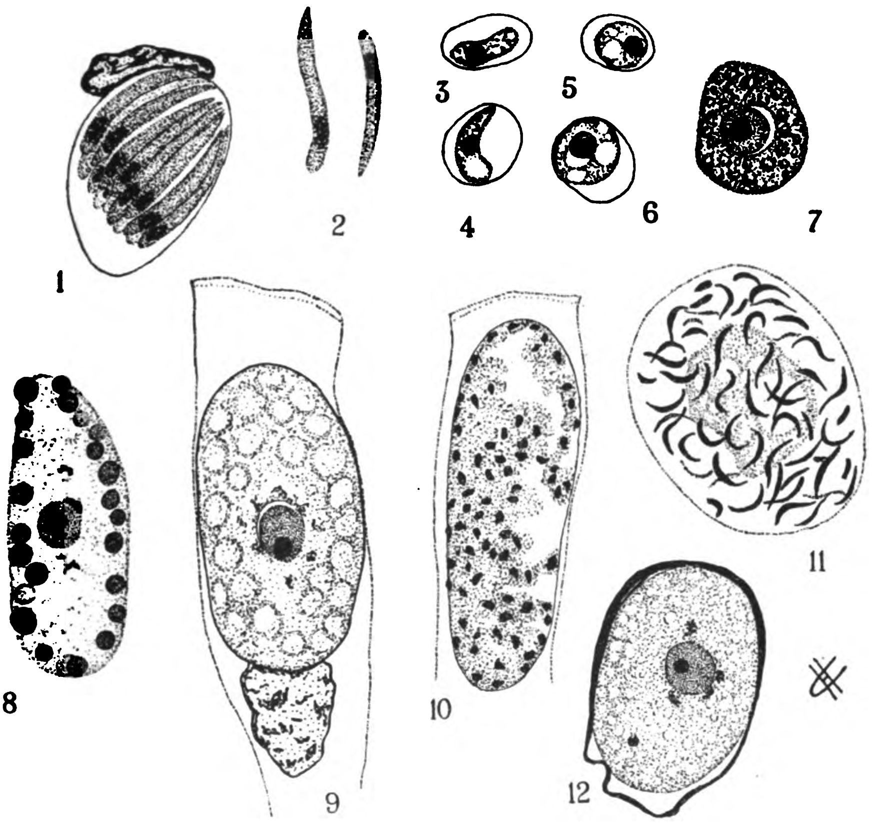

Fig. B. *Eimeria ictidea.* 1.—Final stage of schizogony, showing group of merozoites enclosed in vacuole of host-cell (only the nucleus of latter is drawn). 2.—Two merozoites free in the lumen of the gut. 3-6.—First stages of development of gametocytes (shown within vacuole of host-cell): 3, 4.—Earliest forms—merozoites in the process of shortening and rounding; 5, 6.—Small rounded gametocytes. 7.—Young macrogametocyte. 8.—Mature macrogametocyte containing peripheral globular inclusions. 9.—Macrogamete with cyst-wall in process of formation at the expense of the globular inclusions. 10.—Microgametocyte in process of gamete-formation. 11.—Fully developed microgametes and gametocytic residue. 12.—Oöcyst with zygote (the cyst-wall is crumpled as the result of fixation). (All the stages depicted, except the free merozoites (2), were intracellular. Drawn with the aid of a camera lucida at × 2,000.)

young gametocytes, since on the one hand there is a gradual transition from them to the unmistakable gametocytes (fig. B, 7), and on the other hand none of these or the larger forms showed any signs of nuclear division suggestive of schizogony (cf. *E. furonis*, fig. A, 2, 3).

The stages of gametogony were fully represented. In the young macrogametocyte (fig. B, 7), which measures about 9μ by 7μ, the cytoplasm is packed with granular matter which is later transformed into the dark-staining globules of reserve material characteristic of the fully developed female gametocyte. The latter form is always elongated, measuring about 20μ by 7μ, and occupies the entire enlarged host-cell (fig. B, 8). In the macrogamete or early zygote the cytoplasm is full of vacuoles, the dark reserve material previously contained in them having been used up for the formation of the oöcyst wall (fig. B, 9).

The average size of the oöcyst when discharged with the faeces is about 23·6μ by 17·5μ, the zygote measuring about 15μ by 12μ. The appearance of the oöcyst in sections is shown in fig. B, 12. In all the stages of macrogamete formation the nucleus has the characteristic vesicular structure. The male gametocytes and gametes (fig. B, 10, 11) differ from the corresponding stages of *E. furonis* only in their larger dimensions.

HISTOLOGICAL REACTION PRODUCED BY *E. ICTIDEA*

In an earlier paper (Hoare, 1927) it was noted that the ferrets parasitized by coccidia manifested no outward signs of the infection and that no macroscopic lesions or alterations could be detected in the intestinal mucosa.

In the course of the microscopic examination of sections in connection with the present work it was found that, while infection with *Eimeria furonis* produced no special histological changes (cf. p. 114), in the case of *E. ictidea* there is a very marked tissue reaction of an unusual type.

As already stated, these coccidia invade only the free end of the villus, sometimes only its summit, while the basal portion, usually the greater part of the villus, is uninfected. When the epithelium harbours only the small young forms of the parasites (trophozoites and young gametocytes) the villus retains its normal appearance (fig. C, 1, and Pl. I, A) and does not seem to be altered in any way. However, when the extremity of the villus harbours the large old forms of the coccidium (schizonts, gametocytes, oöcysts) there is evident a tissue reaction which tends to isolate the infected portion from the non-infected one.* This takes the form of an annular constriction which separates the two portions (*cn* in fig. C and Pl. I). It involves the epithelium and extends into the core of the villus to a depth varying with the degree of its development. Apparently in its earliest phase the constriction represents only a slight circular furrow in the epithelium, not deeper than the height of the epithelial cells (*cn* in fig. C, 2 ; Pl. I, B, C) ; later, however, it increases in depth (Pl. I, D, *cn*), penetrating more and more into the core, till the villus assumes an irregular hour-glass shape with a more or less narrow ' waist ' (fig. C, 3, 4 ; Pl. I, E, F).

The parasitized and normal epithelium forming the upper and lower

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*Though the small forms never by themselves call forth the reaction, they are occasionally drawn into the isolated infected area together with the large forms (cf. Pl. I, G).

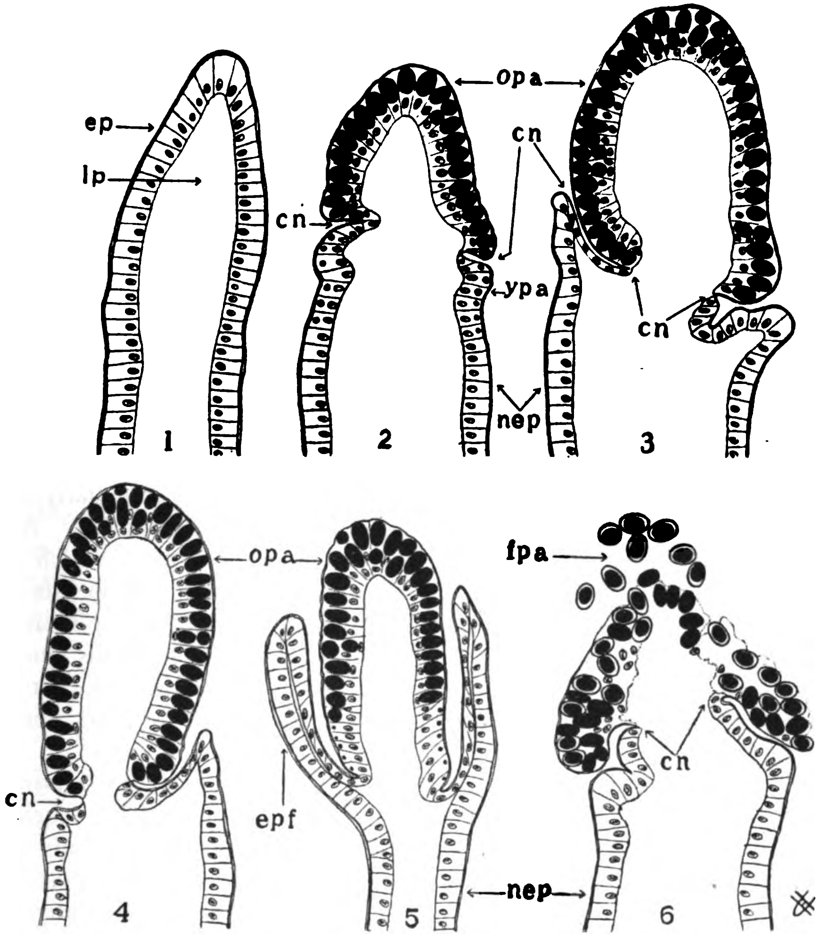

FIG. C. Diagram showing longitudinal sections through the free ends of the villi of the sma intestine in ferrets infected with *Eimeria ictidea.* The coccidia are represented by black circles and ovals, the small ones (*ypa*) denoting the young forms, the large ones (*opa*) the full-grown forms, including oöcysts (*fpa*).

1.—Normal, non-infected villus (*ep* = epithelium, *lp* = lamina propria or core). 2-6.—Infected villi : 2.—Showing the epithelium of the summit of villus invaded by full-grown parasites (*opa*) and separated from the lower portion of the villus by a slight circular constriction (*cn*) ; 3, 4.—Further development of the same process : deeper constrictions (*cn*) isolating infected tip of villus (*opa*) from the non-infected portion (*nep*) ; 5.—Variation of the same reaction : the normal epithelium (*nep*) growing from below produced a fold (*epf*) around infected tip of villus (*opa*) ; 6.—Showing infected extremity of villus breaking up and discharging the fully-developed parasites (*fpa*) into the lumen of the gut. (The figures were outlined with the help of a camera lucida, some af them corresponding to sections depicted in Plate I, viz., 1=A, 2=B, 3=F, 5=G, 6=H. For obbreviations see explanation of Plate I.)

surfaces respectively of the annular constriction face each other and meet at the bottom of the groove. As the constriction deepens the contact between the infected and non-infected epithelium—which forms a continuous layer—is reduced to a thin circular line, seen as a point in section (fig. C, 3, 4, *cn*), so that the infected extremity is supported practically only by the core of the villus.

The infected portions of the villus also show the following pathological changes. The blood-vessels in the lamina propria are dilated and closely packed with erythrocytes (Pl. I, B, *cap*), and in a number of instances extravasation of these elements into the surrounding tissue is evident. Moreover, in the majority of the villi the affected portions manifest various degrees of necrosis (Pl. I, F).

As far as I could ascertain, the reaction just described appears to have no parallel in any other known pathological condition. The formation of the constriction is undoubtedly due mainly to the activity of the sound epithelium of the villus, and the following would appear to be the most plausible interpretation of the processes involved.

It is known that under normal conditions there is a constant desquamation of portions of the epithelium which are being replaced by new cells arising from the crypts of Lieberkühn, the regenerative process being particularly active at the summit of the villi, where the oldest epithelial cells are situated. A similar reparation usually takes place in the case of coccidial infections in which destruction of the epithelium is brought about by the discharge of the oöcysts into the lumen of the gut. Whatever the cause of the local shedding of epithelium may be, compensation is effected by the new epithelial tissue gradually pushing its way over and closing the gap. Under the conditions mentioned above, regenerative proliferation of the epithelium does not take place until its denudation sets in.

The histological reaction observed in infections with *E. ictidea* would appear to represent a modification of the usual type of epithelial regeneration. Since in the infected summit of the villus all the epithelial cells are fully occupied by the large forms of the parasite, it is obvious that the whole of this portion of the epithelium ceases to perform its normal functions and that, from the physiological point of view, it represents a dead, inactive part of the villus. Apparently this condition serves to stimulate the proliferative activity of the epithelial cells at the base of the villus in the same way as a local destruction of the epithelium does, with the result that new epithelial cells are pushed upwards. However, instead of progressing unimpeded, as in cases where there is a gap to be covered, the further advance of the new epithelium is prevented by the inert mass of infected epithelium at the summit of the villus. On reaching this obstruction, the proliferating epithelium, unable to advance, grows inwards, thereby forming a constriction of increasing depth around the core of the villus. Owing to the tension exerted by the active new epithelium at the point where it meets the parasitized epithelium, the contact between them may be reduced to a mere circular line (fig. C, 3, 4, *cn*), and, since this is obviously the weakest point of the epithelial layer, it is easily ruptured here, as shown in Pl. I, I, in which the sound epithelium is disconnected from the infected epithelium and forms a collar-like extension (*epc*) surrounding the summit of the villus. Of course, it is impossible to ascertain from sections whether the rupture and the collar-like projection of the epithelium were brought about by an active process, viz., by the proliferating epithelium actively breaking away from the parasitized epithelium and growing upwards, or whether they were due to post-mortem contraction of the villus under the influence of fixation, in the course of which the epithelium is ruptured at the constriction and the infected tip drawn inwards leaving the newly formed epithelium behind. Whatever the cause of the phenomenon, it demonstrates clearly the ease with which the connection between the infected and non-infected epithelium may be severed.

The same mechanical reasons which lead to the formation of the constriction cause the growing epithelium in this region to be thrown into an annular fold, which frequently develops to such an extent that it surrounds the infected summit of the villus in the form of a cup or sheath (*epf* in fig. C, 5, and Pl. I, G).

The pathological changes observed in the lamina propria of the infected portion of the villus can be attributed to the pressure exerted by the annular epithelial constriction, probably combined with the pressure of the enlarged parasitized cells, while it is conceivable that the parasites themselves may also have some harmful effect upon the tissues. The pressure exerted by the constriction would account for the dilatation of the capillaries (Pl. I, B, *cap*), leading to their congestion with red blood corpuscles and the extravasation of these, and for the resulting focal necrosis of the infected tip of the villus (Pl. I, F), which assumes the character of a sequestrum.

None of the processes, whether degenerative or regenerative, taking place in the infected villus have the slightest effect upon the vitality of the coccidia, which continue their normal development. The usual method by which the mature parasites reach the outer world is by the necrosis of the summit of the villus and the discharge of the coccidial oöcysts (and incidentally other stages) into the lumen of the intestine (*fpa* in fig. C, 6, and Pl. I, H). It is also possible that the infected extremities of the villi may be bodily dislodged from their slender supports (cf. Pl. I, E, F, and fig. C, 3, 4) by the movements of the intestine and its contents.

As regards the significance of the histopathological reaction described, it would appear to be primarily reparative, the formation of constrictions and folds reflecting the obstacles standing in the way of the growing epithelium. The regenerative process can evidently be successfully completed in villi in which the parasites together with the broken up (or intact) extremities are cast off (fig. C, 6 ; Pl. I, H). When this occurs there is no further hindrance to the new epithelium covering up the gap in the normal way. It is doubtful if this reaction can be regarded as of protective importance from the point of view of the host, since it does not check the development of the parasites. However, it is possible that a certain diminution in the number of parasites may take place when the tips of the villi containing immature coccidia break off and are carried away with the faeces.

As is known, the effect produced by coccidia upon their hosts varies considerably, ranging from the local destruction of the intestinal epithelium—which usually has no harmful effect upon the host—to extensive inflammation and necrosis of large areas of the mucosa, accompanied by haemorrhage and other marked pathological symptoms, frequently leading to the death of the host.

As far as it was possible to ascertain from the literature on coccidioses, the peculiar reaction observed in the ferret is unique. It seems probable, however, that similar phenomena are produced by other coccidia, but have been overlooked, since in cases in which no macroscopic lesions are evident and the health of the host is not impaired, the minute microscopic alterations of the tissues produced by the parasites are usually ignored, as being of no practical importance.

In infections with closely related coccidia, especially in those which parasitize the same host, belong to the same genus and differ from each other mainly in quantitative characters, one is frequently struck by the great difference in the effect they produce upon the host. Excellent examples of this are afforded by the six species of *Eimeria* parasitic in domestic fowl (Tyzzer, 1929, and Tyzzer, Theiler and Jones, 1932) and by the two species of the same genus in the ferret. But whereas the fowl-coccidia differ in their localization, some being intra-epithelial, some sub-epithelial, and others in both situations, the localization of the ferret-coccidia is uniform. They both invade the epithelium, and, though the distribution of *E. furonis* in the villus is diffuse, both species are concentrated in masses at the summit, each epithelial cell of which is fully occupied by one (*E. ictidea*) or more parasites (*E. furonis*). The localization and density of the infection being more or less the same in both these parasites, it would appear that the difference in their effect upon the host is due to some difference in their physiological activities.

SUMMARY

A description is given of the endogenous stages of development of the two species of *Eimeria* parasitic in the ferret, *Mustela* (*Putorius*) *putorius* var. *furo*, and of their effect upon the host.

Both coccidia develop exclusively within the epithelial cells of the intestinal mucosa.

E. furonis invades the small intestine and rectum, while *E. ictidea* is found in the small intestine, being localized in the summit of the villi.

E. furonis has no special effect upon the host-tissues, while *E. ictidea* calls forth a peculiar histopathological reaction, viz., the formation of a deep constriction separating the infected summit of the villus from its basal portion.

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EXPLANATION OF PLATE I

Photomicrographs of longitudinal sections through the free ends of villi of the small intestine in ferrets infected with *Eimeria ictidea* (× *ca.* 60). (Cf. text-fig. C.)

Abbreviations: *cap*= capillaries in core of villus ; *cn* = constriction around villus ; *ep* = epithelium of villus ; *epc* = epithelial ' collar ' ; *epf* = epithelial fold ; *fpa* = free (discharged) parasites (oöcysts and gametocytes) ; *lp* = lamina propria or core of villus ; *nep* = normal (non-infected) epithelium of villus ; *opa* = old parasites (chiefly gametocytes) within epithelium ; *ypa* = young parasites within epithelium.

A. Normal, non-infected villus.

B. Infected villus : the epithelium of the summit, harbouring large forms of the parasite (*opa*), is separated from the lower portion of the villus, containing small parasites (*ypa*), by a slight circular constriction (*cn*) ; the capillaries (*cap*) within the core of the villus are dilated and densely crowded with erythrocytes.

C. Infected villus : heavily parasitized summit separated from non-infected lower part by well-defined constriction (*cn*).

D. Villus in which a large portion of the free end is infected and the constriction (*cn*) separating it from the non-infected portion is consequently produced at a lower level.

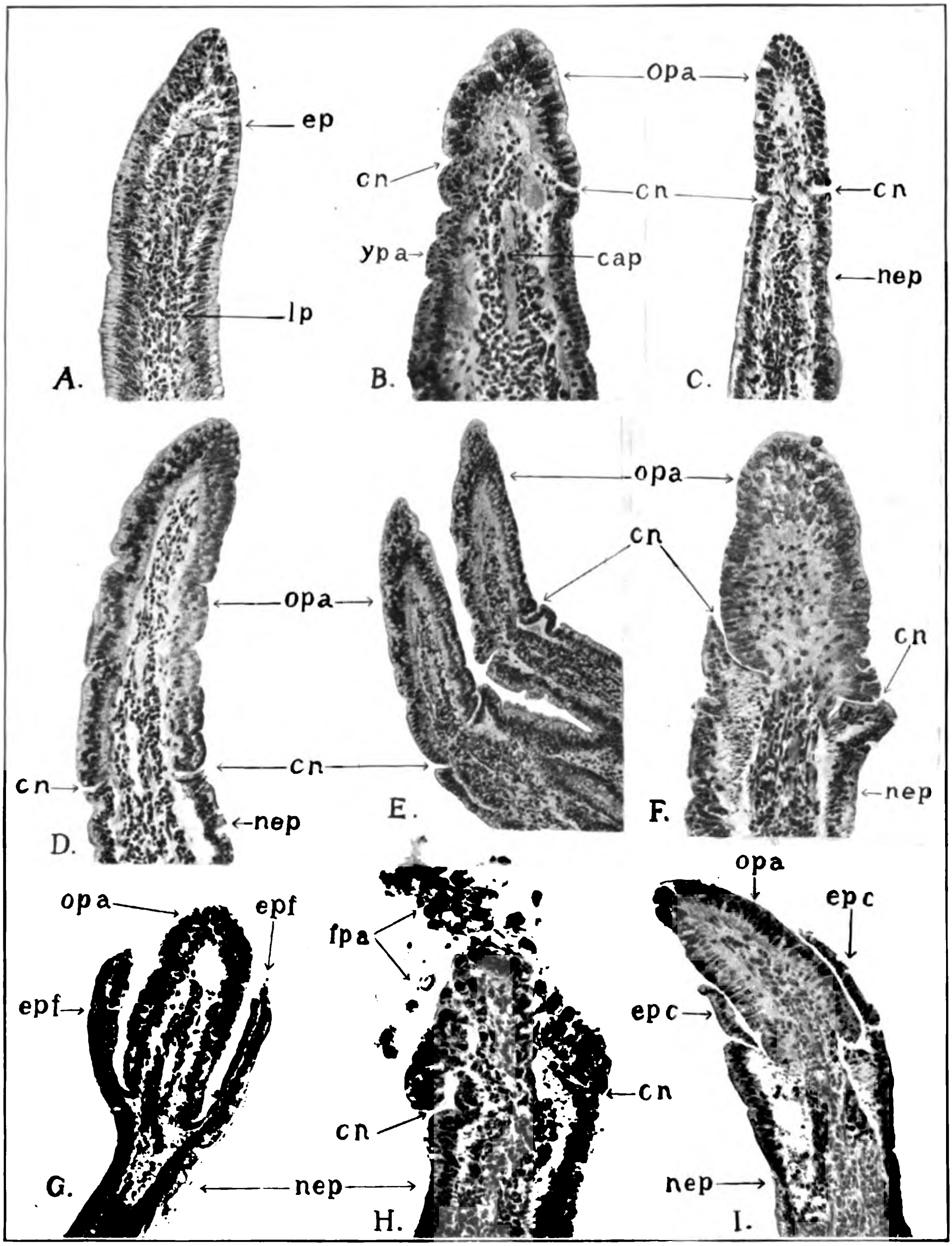
E. Villi with further development of the tissue reaction : deep constrictions (*cn*) separate the infected extremities from the non-infected basal parts of two villi.

F. Villus with very deep constriction (*cn*) between infected tip of villus and non-infected basal portion ; the invaded part is necrotic.

G. Villus in which the proliferating normal epithelium (*nep*) has produced a fold in the form of a cup (*epf*) surrounding the infected extremity (*opa*) ; the latter contains some young parasites in addition to full-grown ones.

H. Villus with extremity breaking up and the parasites (*fpa*) being discharged into the lumen of the gut.

I. Villus in which the proliferating normal epithelium (*nep*) is not continuous with the infected epithelium (*opa*), but forms a collar-like extension (*epc*) around the infected tip of the villus, which is supported only by the lamina propria.



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Haemogregarina tigrinae n. sp. from Natrix tigrina Boie.

(8)

Cecil A. Hoare, B. Sc.

(From the Zootomical Laboratory of the University of Petrograd).

With 10 text-figures.

TIRAGE à PART
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Cecil A. Hoare, B. Sc.

(From the Zootomical Laboratory of the University of Petrograd).

With 10 text-figures.

The material for this note was presented by blood-films from *Natrix tigrina Boie* taken in the summer of 1917 in the vicinity of Tsuruga (Japan) by Dr. W. Roszkowski at my request [1]).

The films were fixed as follows: the film was allowed to dry slightly in the air, then the cover-slip was placed for 15 min. in absolute alcohol, after which the preparation was again dried and preserved till further use. This method is, of course, imperfect and hardly at all superior to the so-called „dry“ fixation on the flame so much opposed by many investigators, however the conditions of work did not allow to apply the more complicated „damp“ fixation. The preparations were stained with the Romanowsky-Giemsa mixture and Delafield's haematoxylin combined with aqueous eosin. Both methods always produced the best results.

I had at my disposal films from the peripheral blood, liver, lungs, spleen and kidneys of different cold-blooded animals [altogether from 24 specimens belonging to the genera *Rana*, *Hyla*, *Gecko*, *Tachydromus* and *Natrix tigrina* (2 spec.)].

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[1]) I take the opportunity of expressing my gratitude to Dr. Roszkowski for his friendly service.

Only the snakes proved to be infected with haemogregarines, the degree of infection being insignificant.

All the forms of haemogregarines found here are intracorpuscular. They measure in the average $12{,}5 - 15{,}5\,\mu \times 3 - 3{,}5\,\mu$. It is possible to distinguish about three types among them: a) bean-shaped, b) vermicular and c) transitory forms.

The bean-shaped forms (fig. 4—9) usually occupy the greater part of the erythrocyte being closely apposed to the nucleus of the latter. Their protoplasm has an alveolar aspect and contains no inclusions. In general, all the bean-shaped forms resemble each other in form of the body and in structure of the protoplasm. The nuclei of these forms are in different stages of division.

The vermicular forms (fig. 1) are of small size (not longer than half of the erythrocyte). Their protoplasm does not exhibit any definite structure; the nucleus is distinctly expressed, oval shaped, staining deeply, and exhibits several fairly large chromatin lumps (about 8).

The transitory forms (fig. 2, 3) occupy an intermediate position between those described both in respect to the form of the body and the structure of the nucleus.

The nuclear structures of the forms described show that we are dealing with part of the cycle of asexual multiplication which agrees closely enough with the typical schizogony in haemogregarines for the first time exhaustively described by Reichenow (1910).

The vermicular form (fig 1) presents a typical merozoite which had, apparently, occupied the blood corpuscle but recently, since the nucleus of the latter has not yet had time to change its normal position and alter its form; or structure under the influence of the parasite. Besides the small size, the compact structure of the nucleus of this form, in which no processes of division are yet visible, also points to its juvenility.

In the course of time the merozoite elongates and assumes the shape of a club, as represented in fig. 2 and 3. In this period the nucleus begins to lose its compact structure and regular outlines, the chromatin lumps become distinctly visible and arranged loosely in the plasm. Such a form of the body and arrangement of the nuclear elements are characteristic of the young schizont. In the same period the chromatin lumps begin to arrange themselves in the form of a network

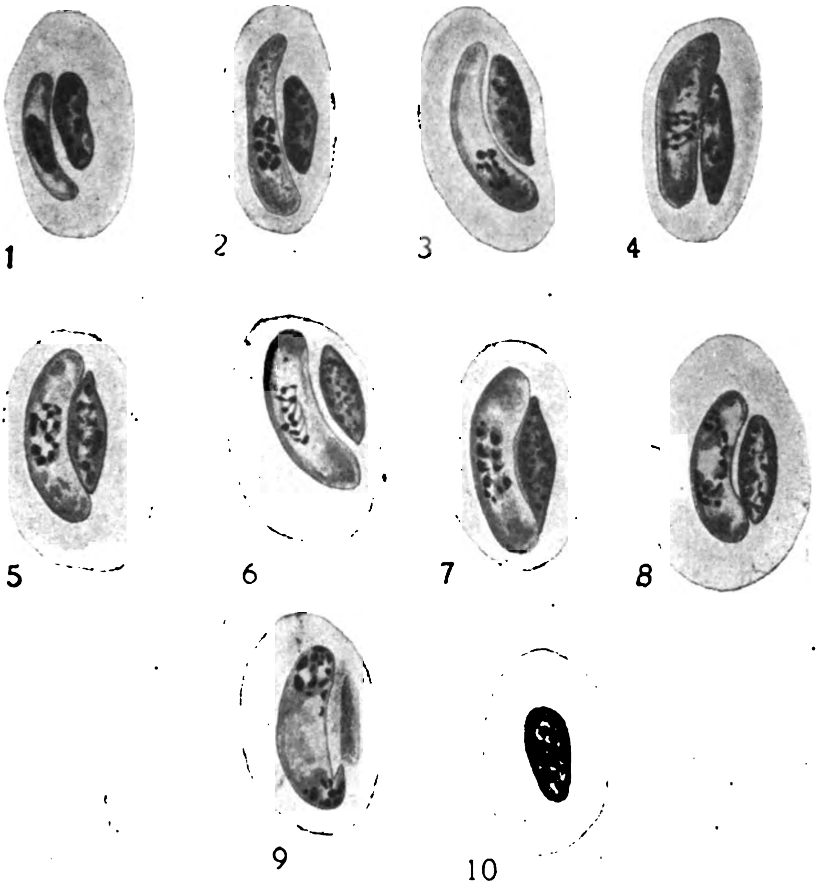

Fig. 1.—Merozoite.
Fig. 2, 3.—Young schizonts.
Fig. 4, 5, 6.—Mature schizonts. Formation of nuclear network.
Fig. 7.—Mature schizonts. Breaking up of the nuclear network into separate chromatin lumps.
Fig. 8, 9.—Mature schizonts. Division of the nucleus.
Fig. 10.—Normal erythrocyte of the snake.

All the figures have been drawn with the help of Leitz's camera lucida, at a magnification of about × 1.500 (Leitz, oc. 4, imm. obj. $^{1}/_{12}$).

or band (fig 3, 4); this reticular or band-shaped structure [Reichenow (1910) and Prowazek (1907) describe it in the form of a single coiled band] becomes quite distinctly expressed in the succeeding stage—the mature schizont (fig. 5, 6).

The processes described always precede all the stages of division in haemogregarines.

Next follows the breaking up of the network, or band, into separate chromatin lumps which increase in dimensions, evidently at the expense of the reserve nuclear matter of the protoplasm (fig. 7). In our forms the volutin granules usually present in this stage are absent, however the fact that the protoplasm stains with nuclear stains at this period signifies that the formation of nuclear substances does take place in it.

The next stage (fig. 8) already presents division of the nucleus by means of a simple separation of the chromatin complex into two groups which diverge in opposite directions. Figure 9 represents the ultimate phase of division: the daughter-nuclei are already separated and have become arranged at the poles.

I did not observe the final stages of schizogony in my preparations. The processes described provide further evidence corroborating Reichenow's observations on the asexual cycle in haemogregarines.

Around the majority of forms a weakly expressed membrane is visible.

There is one question more to be elucidated. During schizogony in haemogregarines we usually observe that by degree as the parasite grows, one end of its body bends over the other and finally reaches the other end, but at the approach of division the second limb is again drawn in, or otherwise reduced. Only after repeated asexual multiplication, when schizogony already leads to the formation of sexually differentiated merozoites, the second limb is not formed at all. In my preparations I have not even found traces of a second limb in any of the stages, only in the final stage I encountered a form with a slight hook at one end (fig. 9). The latter form, as well as the elongation of the merozoite distinctly expressed in the beginning of the schizogony (fig. 2, 3) indicate that the bending, probably, takes place in our case as well, but the reduction of the second limb takes place before the nucleus has started to divide, whilst in one case (fig. 9) this reduction may have been retarded.

All the stages described, except the final ones, were encountered in the peripheral blood. The stages of division (fig. 8, 9) are from the blood of the kidneys. Probably, the final formation of the merozoites also takes place in these organs.

The influence of the parasite upon the blood-corpuscles of the host manifests itself, first of all, in nearly complete dehaemoglobinization of the erythrocyte, only a shadow of the latter being visible, whilst its outlines are hardly distinguishable (fig. 7 & 9 give some idea of this picture). The alterations undergone by the nucleus of the erythrocyte are less expressed and defined. On comparing a successive series of stages it can be noted that the nucleus gradually assumes a more regular spindle shape, evidently due to mechanical causes, viz. to pressure from the part of the parasite and the substance of the erythrocyte; it slightly increases in volume, whilst its chromatin becomes distributed more loosely. The parasite, possibly, evokes something like colliquative degeneration in the nucleus of the host-cell, which causes it to swell and, maybe, leads to its destruction, as the aspect of the nucleus in fig. 9 shows (such pictures are, however, rarely encountered).

In determining the systematic position of our parasite it is necessary to decide between the genera *Haemogregarina* and *Karyolysus* since in the absence of a better criterion—the sexual cycle—we are compelled to be guided by two characters—the morphological resemblance of all the forms encountered here with the typical representative of the genus *Haemogregarina, H. stepanowi Dan.*, and the pathological action of the parasite, peculiar to the genus *Karyolysus*. In face of such obstacles, I refer our form provisionally to the collective genus *Haemogregarina* (For particulars regarding the question of classification of haemogregarines see: Reichenow, 1912; Hoare).

As far as I could ascertain, in the limits of the genus *Natrix* (*Tropidonotus*) haemogregarines have hitherto been found only in *Natrix piscator* (*Haemogregarina mirabilis*) by Castellani and Willey (1904), in *N. stolatus* by Billet

(1895), and in *N. viperinus* (*H. viperini*) by the same author (1904). None of these forms differ markedly from the generic type of *Haemogregarina*, except, maybe, *H. viperini* which behaves quite like *Karyolysus*, destroying the nucleus of the host-cell completely and decolorizing the plasm of the latter.

Our parasite cannot be referred to any of the species just named; and since its host, *Natrix tigrina*, has not hitherto been known to harbour haemogregarines, I suggest for this parasite the name *Haemogregarina tigrinae*.

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(9)

Hepatozoon Adiei, N.Sp.

A Blood Parasite of an Indian Eagle.

BY

CECIL A. HOARE, B.Sc.

Protozoologist to the Wellcome Bureau of Scientific Research, London.

(Paper presented at a Meeting of the Royal Society of Tropical Medicine and Hygiene, Thursday, 15th May, 1924).

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HEPATOZOON ADIEI, N.Sp.

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BY

CECIL A. HOARE, B.Sc.

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The material on which this paper is based was kindly presented to the Bureau by Mrs. H. A. ADIE, and consisted of blood- and organ-smears made from an eagle* in April, 1917, at Kasauli, Punjab, India. In the preparations, stained by LEISHMAN'S method, Mrs. ADIE discovered a parasite which she identified as a hæmogregarine. This finding is of considerable interest, as the few hæmogregarines hitherto recorded from birds have not been accepted generally, the majority of authors regarding them as toxoplasmas rather than hæmogregarines.

The material available consisted of smears from the lung, liver, spleen, kidney, bone-marrow, intestine, and brain, as well as numerous blood-films. The parasites were found almost exclusively in the blood and lungs, only isolated forms occurring in the spleen.

The majority of forms found in the lung (Plate, Figs. 1-5) have the typical appearance of hæmogregarine schizonts in different stages of development. In shape they are more or less regularly ovoid, and measure from 8μ by $4{\cdot}8\mu$ (Fig. 3) to $20{\cdot}8\mu$ by $11{\cdot}2\mu$ (Fig. 5), the majority being intermediate in size (Fig. 2). In most of the schizonts seen nuclear multiplication had already taken place, from twelve to twenty-four nuclei being present. In some forms schizogony had reached the final stages, in which the formation of merozoites could be observed (Figs. 4-5). As all the smears had been dried, and as no sections of properly fixed material were available, it was impossible to make out the true structure of the nuclei and merozoites. As far as can be seen, the latter are elongated and vermiform, and similar to the typical merozoites of other known hæmogregarines (Figs. 4, 5). The younger schizonts (Figs. 1-3) are enclosed in definite cells, probably endothelial cells of the capillaries, as is the case with *Karyolysus*. In the later stages of schizogony (Figs. 4, 5) the growth of the parasite has reduced the host-cell to a thin membrane, with the flattened nucleus at one side of it (Fig. 5).

The forms encountered in the peripheral blood of the eagle are uniform in type (Figs. 6-10). The shape is that of a thick, short rod, rounded at its extremities and measuring on the average 8·5μ by 4·5μ. The nucleus is usually terminal in position. All the forms seen were enclosed in leucocytes of the large mononuclear or transitional type. They are in close association with the leucocyte nuclei, the parasites either displacing or being wedged into them. In the latter case the nucleus of the leucocyte surrounds the parasite to a varying extent and may even be broken up into several portions. This, however, may be a result of a flattening of the nucleus, which occurs during the drying of films. From the point of view of the morphology of the various stages described, and their habitat, the parasite corresponds with a typical hæmogregarine. In the absence of any knowledge of a complete cycle of development in the vertebrate and invertebrate hosts, it is difficult to determine the precise systematic position of this hæmogregarine. The fact, however, that in the peripheral blood it is found exclusively in leucocytes and is morphologically indistinguishable from the corresponding stages of the hæmogregarines of rats (Fig. 11) and dogs (Fig. 12), would appear to justify the inclusion of the parasite in the genus *Hepatozoon* to which the parasites of the dog and rat belong.* As in the case of the mammalian-hæmogregarines, the leucocytic stages of the bird-hæmogregarine may be regarded as gametocytes, especially as all the forms encountered in the blood are of a uniform type and in the same stage of development.

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*Unfortunately it is impossible to give the name of the bird, as it had not been identified.

Referring this parasite provisionally to the genus *Hepatozoon,* I propose to name it *Hepatozoon adiei,* in honour of its discoverer.

Whether hæmogregarines have previously been seen in birds is still a disputed point. ARAGÃO (1911) was the first to refer certain hæmatozoa found by him in seven Brazilian birds to the genus *Hæmogregarina.* They were accepted by REICHENOW (1912), who gives the number of species occurring in birds as seven. ARAGÃO's preparations were re-examined by MIGLIANO (1913), who came to the conclusion that the parasites in question were toxoplasmas. Similar parasites were again observed by CARINI and MACIEL (1916) in a number of Brazilian birds which included some of the species with which ARAGÃO worked. The last-named authors also referred their parasites to the toxoplasmas. The hæmogregarines described by ARAGÃO are definitely transferred to the genus *Toxoplasma* in a recent article by NÖLLER (1920).

The disagreement regarding ARAGÃO's parasites can be understood easily on reference to his description and figures. According to ARAGÃO (1911), the bird-hæmogregarines are enclosed within leucocytes in "erwachsenen Zustande," and measure up to 8·2μ in length. Schizogony is said to take place in the cells of the internal organs, the merozoites being very small and irregularly distributed in the cells containing them. In a summary description the author links all the forms of the parasites observed by him into one developmental series. The "grown-up" forms referred to have the appearance of typical hæmogregarines, whereas the "merozoites" cannot be compared with any known stages of development in hæmogregarines; they are, in fact,

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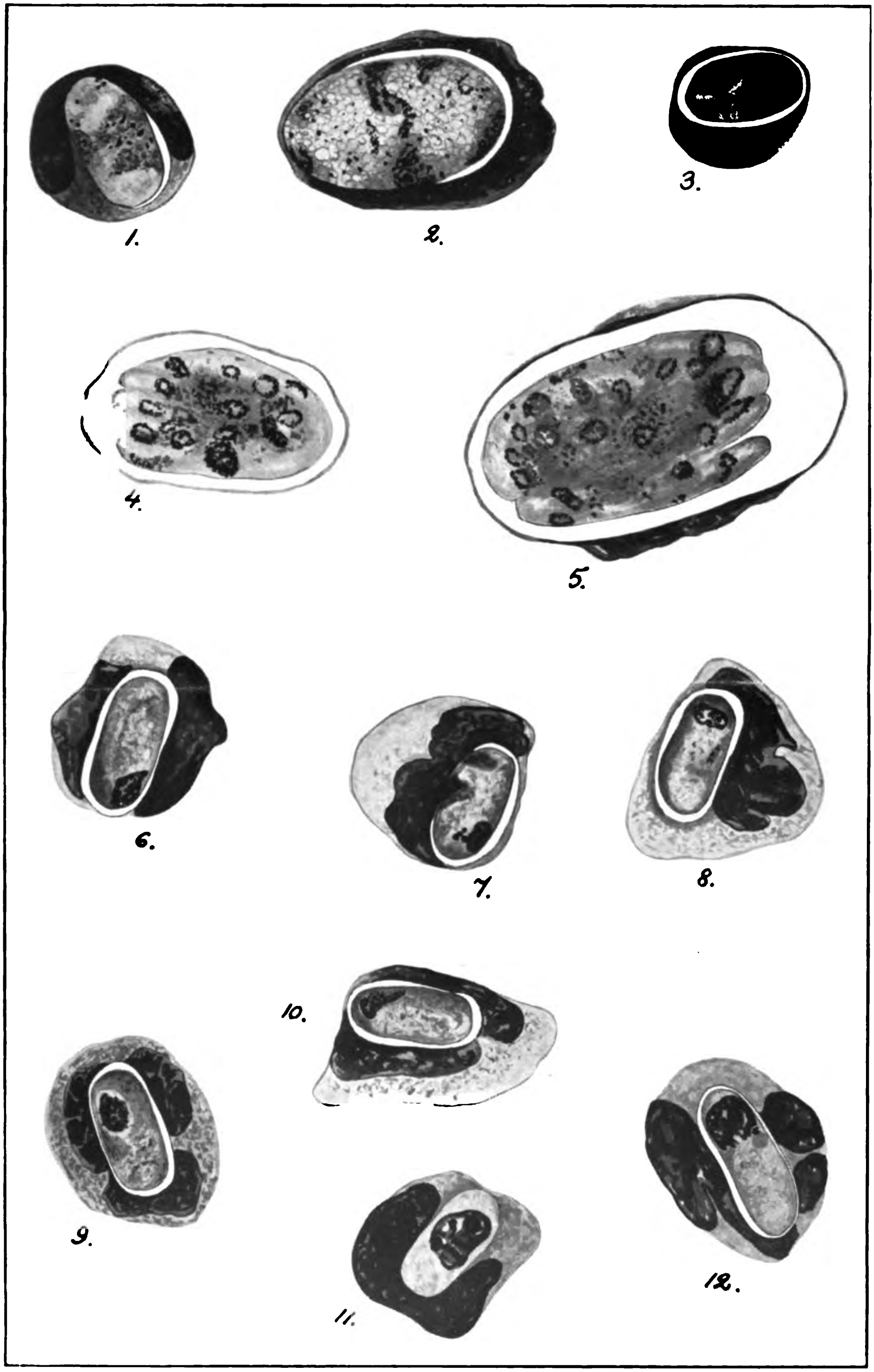
*The figures of *Hepatozoon muris* (Fig. 11) and *H. canis* (Fig. 12) were drawn from dry fixed films stained by LEISHMAN's method, and are reproduced for comparison with the parasite of the eagle.



C. A. Hoare, *del.*] [*To face page 64.*

Illustration to accompany Mr. Hoare's Paper.

indistinguishable from the organisms known as toxoplasmas. That this similarity was recognised by Aragão himself is shown by the fact that he compares the parasites described by Laveran (1900) from *Padda orizivora*, and by J. R. Adie (1908) from the Indian sparrow, with the forms observed by him, and refers the former to the same genus *Hæmogregarina*. In the case of the parasites described by Laveran and by Adie, there are no stages which correspond with hæmogregarines. They resemble Aragão's "merozoites," and are generally recognised as toxoplasmas. If Aragão's description (1911, pp. 60-63) of his species of hæmogregarines is compared with the corresponding figures, it will be found that in five birds (*Atticora cyanoleuca*, *Rhamphocœlus brasilius*, *Paroaria larvata*, *Tanagra palmarum* and *Brachyspiza capensis*) Aragão found only the leucocytic "grown-up" parasites, and no stages of schizogony, whereas in only two birds (*Sporophila albigularis* and *Sycalis flaveola*) did he find the small forms resulting from "schizogony," and in them no "grown-up" forms occurred. It thus seems clear that Aragão must have observed *two* distinct types of parasites in the seven birds examined—hæmogregarines and toxoplasmas—which he rather arbitrarily united into one developmental cycle.

The "grown-up" forms described by Aragão have all the characteristic features of typical hæmogregarines and, similarly to the form described in this paper, they inhabit leucocytes.. It is quite possible, therefore, that Aragão gave the first description of a *Hepatozoon* infection in birds. The body of Aragão's parasites appears to be more flexible than that of the form described here, while the nucleus is more distinctly depicted. This difference is undoubtedly due to the fact that Aragão's preparations were fixed by the "wet" method (Schaudinn's fluid). I have examined a number of films of *Hepatozoon muris* from Dr. Wenyon's collection, which were fixed by this method, and found that the parasites were similar in appearance to Aragão's hæmogregarines, whereas, when fixed dry, they are practically indistinguishable from *H. adiei* (Fig. 11). It is probable that Carini and Maciel (1916) were also dealing with a mixed infection of hæmogregarines (vermicular forms measuring $8{\cdot}5\mu$ by $3{\cdot}5\mu$ enclosed in mononuclear leucocytes) and toxoplasmas in birds. Other references to hæmogregarines in birds appear in papers by Fantham (1919) and Franchini (1923), but their descriptions are such that no conclusion can be based on them.

Assuming that the parasites described by Aragão (1911) belong to the genus *Hepatozoon*, as there is every reason to believe, we have the following provisional list of hæmogregarines found up to the present in birds:—

Hepatozoon atticoræ	(Aragão, 1911) emend.	Brazil.
H. rhamphocœli	,, ,, ,,	
H. paroariæ	,, ,, ,,	
H. tanagræ	,, ,, ,,	
H. brachyspizæ	,, ,, ,,	
H. adiei mihi, India.		

It is possible that the birds examined by Carini and Maciel (1916) harboured hæmogregarines, but as these authors only give a general description of the parasites (hæmogregarines and toxoplasmas) found in all the birds, it is not possible to allocate any parasite to a particular host.

EXPLANATION OF FIGURES IN PLATE.

(All the figures were drawn with a camera lucida at a magnification of 2,000 diameters. The specimens represented in this plate were fixed dry and stained by LEISHMAN'S method.)

Figs. 1-5.—*Hepatozoon adiei*, n.sp. Stages of schizogony in the lung of the eagle.

Figs. 6-10.—Same. Gametocytes in leucocytes of the peripheral blood.

Fig. 11.—*H. muris* (= *H. perniciosum*). Gametocyte.

Fig. 12.—*H. canis*.—Gametocyte.

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Vol. XVII., Nos. 6 & 7, pp. 403-406. 17th January, 1924.]

A NOTE ON THE SPECIFIC NAME OF THE HERPETOMONAD OF THE HOUSE-FLY.

BY CECIL A. HOARE, B.Sc.
(Wellcome Bureau of Scientific Research).

In a recent paper, BECKER (1923) discussed the nomenclature of the flagellate of the house-fly, known as *Herpetomonas muscæ-domesticæ*. As is known, the specific name of this parasite is generally ascribed to BURNETT (1851-1852), although, as BECKER remarks, BURNETT referred to it only as "*Bodo* . . . of the common House-fly." In 1856 the flagellate was named *Bodo muscarum* by LEIDY, while in 1878 STEIN referred to it as *Cercomonas muscæ-domesticæ*. It would appear that LEIDY's name has priority over STEIN's, but BECKER (1923) rejected the former as a *nomen nudum* on the grounds of the absence in LEIDY's paper of a "recognisable description of the parasite or a reference to BURNETT's description."

I had interested myself in the question of the nomenclature of this parasite before BECKER's paper appeared, and as I cannot agree with his conclusions it appeared to be an opportune moment for publishing a note on the history of the question. This is all the more desirable since no one, except BECKER and some of the earlier authors, seems to have consulted the original publications dealing with the subject, with the result that LEIDY's contribution has not had the recognition it deserves.

As mentioned above, the specific name "*muscæ-domesticæ*" for the house-fly Herpetomonad was attributed to BURNETT, some authors giving the date of his paper as 1851, others, as 1852. As a matter of fact, BURNETT read a paper before the Boston Society of Natural History on 5th November, 1851. An extract of this paper was published later in the same year (BURNETT, 1851), whereas its complete text appeared next year (BURNETT, 1852). In both papers BURNETT described "Monads forming the genus *Bodo* (EHR.) . . . which are found in the intestines of the common house-fly." A recognisable description of the Herpetomonad of the house-fly is given, but in neither of these publications did BURNETT give a specific name to the flagellate. That he never even attempted to do so is clearly shown by the following words: "such differences [between representatives of the genus *Bodo*] should not be made the basis of specific distinction" (1851), and "these differences can never serve as the basis of *Species*" (1852). In view of these statements, it is astonishing to find different writers quoting BURNETT as the author of a specific name for this Herpetomonad.

Several years later, LEIDY (1856) published a " Synopsis of Entozoa " in which the following record is made :—

> " *Bodo muscarum* LEIDY.
>
> Frequent in the intestine of the house-fly, *Musca domestica*, in immense quantity."

The next reference to the nomenclature of the fly-herpetomonad appears in STEIN'S monograph (1878), where he makes the following statement (l.c., p. 79) : " Als weiter neue Arten bezeichnet er [LEIDY] . . . *Bodo muscarum* aus dem Darm der Stubenfliege. Letzter Art war aber schon einige Jahre früher von BURNETT entdeckt und *Bodo Muscæ domesticæ* genannt worden," and further—" alle diese Arten [of *Bodo*] sind keine wahren Bodonen, sondern *B. helicis, Juli, muscarum* und *colubrorum* gehören entschieden in die Gatt. *Cercomonas* DUJ." At the end of this volume the following explanation of figures referring to this flagellate appears (STEIN, 1878 : Pl. 1, Abt. II, Figs. 1-4) :—" *Cercomonas Muscæ domesticæ* STEIN (*Bodo Muscæ domesticæ* BURNETT. *Cercomonas muscarum* LEIDY)."

From these quotations it is seen that STEIN was the first wrongly to attribute the specific name " *muscæ domesticæ*" to BURNETT, and his statement was copied by all subsequent writers, the majority of whom did not even take the trouble to verify the statement by reference to BURNETT'S original papers. This refers particularly to recent authors. There seems to be no doubt that STEIN and his contemporaries were acquainted with BURNETT'S papers, so that their misstatements require another explanation. It will be noticed that, according to STEIN (1879) BURNETT named the parasite "*Bodo Muscæ domesticæ*"; LEUCKART (1879) referred to it as " Cercomonas Muscæ . . . (nach STEIN) " (l.c., pp. 303 and 300 resp.), and BÜTSCHLI called it "*Herpetomonas Muscæ* BURN." BURNETT (1851), as we have seen, referred to the parasite only as " Bodo . . . of the common House-fly." A comparison of BURNETT'S words with those of the writers named shows that the latter had simply *translated* BURNETT'S words " of the . . . House-fly " into the Latin equivalent "Muscæ domesticæ" (STEIN), or in brief, " Muscæ " (LEUCKART, BÜTSCHLI), even using a capital " M ", where BURNETT (1851) used a capital " H."

As already mentioned, LEIDY'S (1856) name "*Bodo muscarum*" is regarded by BECKER (1923) as a *nomen nudum*, preference being given to STEIN'S specification "*muscæ domesticæ*." The Law of Priority in the International Rules of Zoological Nomenclature (1913) reads as follows :—

> " Art. 25.—The valid name of a genus or species can be only that name under which it was first designated on the condition :
>
> *(a)* That this name was published and accompanied by an indication, or a definition, or a description."

LEIDY'S name complies with the main rule, but is not " accompanied by a definition, or a description." There can be no doubt, however, that sufficient " indication " for recognising the flagellate was given.

In the first place, we know of no other protozoon, but the *Herpetomonas*, which, to use LEIDY's (1856) own words, is "frequent in the intestine of the house-fly, *Musca domestica*, in immense quantity"; secondly, all writers on this subject identified LEIDY's "*Bodo muscarum*" with the flagellate in question. The above quotation from STEIN's work (1878) leaves no doubt on this point, whilst GRASSI (1881) even adopted "*muscarum*" as the correct specific name.

It is not generally known that LEIDY already in 1851 had seen the Herpetomonad of the fly, and in a paper published two years later (LEIDY, 1853) had referred to it in the following terms (l.c., p. 13): "Parasitic germs may be readily introduced into the animal, as in the case of the common house-fly, which often contains myriads of a species of *Bodo*." Thus, in this publication which appeared only a year later than BURNETT's paper (BURNETT, 1852) LEIDY also speaks of a *Bodo* of the common house-fly. At present it is not possible to ascertain if LEIDY at this time was or was not acquainted with BURNETT's description of the fly-flagellate. Most probably he was not, as his paper was accepted for publication in December, 1851, while BURNETT's was not published till 1852. LEIDY may have had access to the extract of BURNETT's paper published after 5th November, in 1851, but we have no means of verifying this. It is clear that in specifying the *Bodo* of the house-fly as "*Bodo muscarum* LEIDY" he (LEIDY, 1856) was creating a new name for the parasite mentioned by him in 1851 (LEIDY, 1853). There can be no doubt that in both cases he was dealing with the parasite described by BURNETT and now known as *Herpetomonas musçæ-domesticæ*.

It thus appears that there are no grounds for rejecting the specific name "*muscarum*" which becomes the correct specific name of the *Herpetomonas* of the house-fly.

It must be noted, however, that there exists an amendment to the Rules of Zoological Nomenclature which apparently gives support to BECKER's view. In "Opinion 1" the meaning of the word "indication" in Art. 25 *a* is explained as "(1) a bibliographic reference, or (2) a published figure (illustration), or (3) a definite citation of an earlier name for which a new name is proposed."

Even if this clause is confirmed by the next Zoological Congress, it will not invalidate the priority of LEIDY's name, since STEIN (1878) recognises the name *Bodo muscarum* LEIDY, 1856, and changes it to *Cercomonas muscarum* on the same page of his work (l.c., p. 79). It is not apparent from the *text* that he wished to adopt the specific name "*muscæ domesticæ*" which he erroneously attributed to BURNETT. The suggestion of a new name—*Cercomonas muscæ domesticæ* STEIN—only appears at the end of the volume (and not elsewhere), in the explanation of figures illustrating the flagellate (see quotations on p. 2-3). Thus it is clear that the specific name "*muscarum*" has priority over "*muscæ domesticæ*" even if we base our arguments on STEIN's work alone, where its priority is established by page precedence (Art. 28, Recommendation *c*. of the Rules of Zoological Nomenclature).

The correct name of this flagellate is, therefore, *Herpetomonas muscarum* (LEIDY, 1856) KENT, 1881, with the following synonyms:—

Bodo of the common House-fly, **Burnett**, 1851.
Bodo of the common House-fly, **Leidy**, 1853.
Bodo muscarum, **Leidy**, 1856.
Bodo Muscæ domesticæ, **Stein**, 1878 (*nec* **Burnett**).
Cercomonas muscarum (**Leidy**, 1856) **Stein**, 1878.
Cercomonas Muscæ domesticæ, **Stein**, 1878.
Cercomonas Muscæ, **Leuckart**, 1879.
Herpetomonas muscæ-domesticæ, **Kent**, 1881 (*nec* **Burnett**).
Monomita Muscarum (**Leidy**, 1856) **Grassi**, 1881.
Herpetomonas Muscæ, **Bütschli**, 1884 (*nec* **Burnett**).

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TRANSACTIONS OF THE ROYAL SOCIETY OF
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NOTE ON *TRYPANOSOMA SIMIAE* FROM AN OUTBREAK AMONGST PIGS IN THE GOLD COAST.

BY
CECIL A. HOARE, D.Sc.,
Protozoologist to the Wellcome Bureau of Scientific Research, London.

In a recent paper (HOARE, 1936) an account was given of all the recorded cases of acute porcine trypanosomiasis in Africa, attributable to *Trypanosoma simiae*, and it was noted that, with one possible exception, they were all distributed in the east-central region of the continent.

The only epizootic outbreak reported from West Africa occurred in Mamou, French Guinea. From the description given by ALDIGÉ (1920) it was concluded that the disease was due to *T. simiae*.

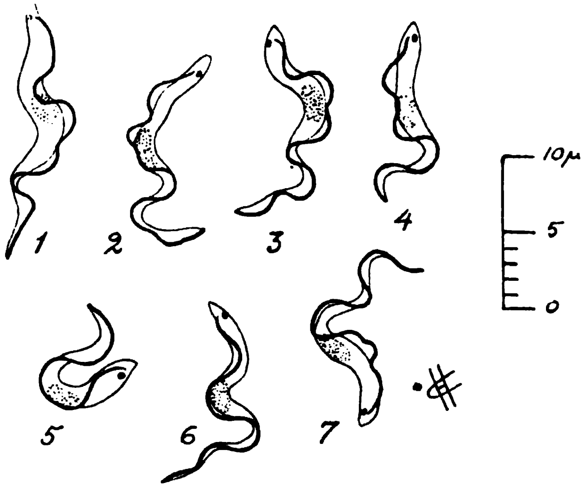
An outbreak in the Gold Coast described by STEWART in the present issue of the TRANSACTIONS (p. 313) represents the first authentic record of *T. simiae* infection in West Africa. It thus extends the distribution of this trypanosome and, furthermore, lends support to my interpretation of the aetiology of ALDIGÉ'S case.

TABLE.
T. simiae FROM PIGS IN THE GOLD COAST.
DISTRIBUTION (PER CENT.) OF FORMS WITH RESPECT TO POLYMORPHISM AND FREE FLAGELLUM.

Variety of Forms.			Free Flagellum.			Number of Trypanosomes Examined.
simiae-typical.	*rhodhaini*-like.	*congolense*-like.	Absent.	Apparent.	Present.	
91·0	7·0	2·0	96·0	3·2	0·8	584

Capt. J. L. STEWART was kind enough to supply me with a collection of stained and unstained blood-films taken from infected pigs at Kumasi, Ashanti. Having confirmed Capt. STEWART'S diagnosis of *T. simiae*, I availed myself of the opportunity to make a further study of this trypanosome, with the object of checking my previous findings regarding its specific characters (HOARE, 1936). A critical examination of preparations from fresh cases, and especially from new localities, was desirable in view of the fact that in *T. simiae* we are dealing with a species, the position of which among other trypanosomes pathogenic to domestic animals has only recently been recognized.

The appearance of the trypanosomes from the Ashanti pigs is shown in the text figure. They exhibit the same polymorphism as *T. simiae* from other parts of Africa, *viz.*, the classical *simiae*-forms with a well-developed undulating membrane (Figs. 1 to 4), the slender (*rodhaini*-like) forms with an undeveloped membrane (Fig. 6) and *congolense*-like forms (Fig. 5). As is shown in the accompanying table, the proportion in which these forms occur also agrees very closely with the corresponding figures for the East African strains (cf. HOARE, *loc. cit.*, Table II). The measurements of the West and East African strains of *T. simiae* are likewise within the same range. There remains the question of the free flagellum. This was found to be definitely absent in 96 per cent. of the trypanosomes examined; in 3·2 per cent. a free portion of the flagellum is apparently (but by no means certainly—see argument in HOARE, *loc. cit.*, p. 632 *et seq.*) present, while only in 0·8 per cent. does a free flagellum seem to be actually present (Fig. 7). If these figures (see table on page 315) are compared with those for the eastern strains (cf. HOARE, *loc. cit.*, Table III), it will be seen that in the West African strain the absence of a free flagellum is more universal. However, in my opinion, this is not due to any difference between the various strains, but to the fact that the examination of the Gold Coast strain was based on well-stained *recent* preparations, while those examined by me previously were several years old. In the fresh films the delicate portion of the undulating membrane which runs to the tip of the flagellum and which becomes obliterated with time and in defective preparations, can be detected in the majority of the trypanosomes, leaving only a small number (0·8 per cent.) in which there appears to be a short free flagellum.



Trypanosoma simiae FROM THE GOLD COAST.
1-4. Predominant "*simae*"-forms; 5. "*congolense*"-like form; 6. "*rodhaini*"-like form; 7. Form with free flagellum.
(Drawn with the aid of a camera lucida, at ×2000).

It is thus seen that both qualitatively and quantitatively *T. simiae* from the Gold Coast pigs reveals the same features as the other strains of this trypanosome described by me. This fact provides further evidence that the polymorphism of *T. simiae* is not due to mixed infections, but represents a constant characteristic of this species.

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On a New *Dactylosoma* Occurring in Fish of Victoria Nyanza

CECIL A. HOARE, D.Sc.

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ON A NEW *DACTYLOSOMA* OCCURRING IN FISH OF VICTORIA NYANZA

BY

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(*Received for publication* 8 *April,* 1930)

INTRODUCTION

While working at the Human Trypanosomiasis Research Institute, Entebbe, Uganda (1927-1929), I had the opportunity of examining a number of fish from Lake Victoria, belonging to the genus *Haplochromis*. These small fish, only a few inches long, are known locally as 'Enkeje.' They are caught in large numbers by the Baganda fishermen, dried in the sun and used as an article of diet. The species examined by me for parasites were *Haplochromis humilior*, *H. nubilus*, *H. cinereus*, *H. serranus* and *H.* sp.* Members of all these species, except the first named, were found to be infected with a *Dactylosoma*.

As is known, the genus *Dactylosoma* is represented by intracellular blood-parasites belonging to the order Coccidiida; its precise systematic position has not been definitely established, but it appears to be related to both the Haemosporidiidea and the Piroplasmidea. Hitherto these parasites have been recorded only for amphibia (frogs and newts). Wenyon (1926) believed that the organism found by Awerinzew (1914) in *Chamaeleon fischeri* and named *Lankesterella amania* was allied to *Dactylosoma* and he accordingly changed its name to *D. amaniae*. Dr. Wenyon informs me, however, that he was unable to consult Awerinzew's original publication—which, as far as I am aware, is unobtainable in this country—and his conclusions were, therefore, based on an abstract of the paper. Through the courtesy of Dr. H. Epstein, of Moscow University, I had the opportunity of consulting Awerinzew's work in Russian and was able to confirm Wenyon's contention that the chameleon parasite does not belong to the genus *Lankesterella*. On the other hand there do not appear to be sufficient grounds for referring it to *Dactylosoma*.

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* I wish to acknowledge my indebtedness to Mr. J. R. Norman, of the British Museum (Natural History) for the identification of these fish.

The journal in which Awerinzew's paper was published being inaccessible to English readers, the following free translation of his description of the chameleon parasite may be of interest.

> 'I was able to follow the vegetative multiplication of the haemogregarine described with sufficient completeness in blood-films of *Chamaeleon fischeri*. One usually finds in the erythrocyte only one haemogregarine representing a very small globule with a sharply stained central body. No membrane was found around the parasite. The central sharply-staining body I regard as a nucleus and the thin external layer surrounding this body—as the protoplasm. The haemogregarine gradually grows and increases in volume, but no sharp differentiation of the nuclear and protoplasmatic parts can be observed in it. There is no accumulation of pigment or any other alterations in the parasite, nor does it produce any visible destructive action upon the erythrocyte. When the haemogregarine reaches a fairly large size division of its nucleus leading to the breaking up of the entire organism into parts can be observed. The nucleus divides at once into six nuclei. The final stages of this division resemble somewhat similar stages in the division of the nucleus of *Calcituba polymorpha* [Foraminifera], described by Schaudinn. From the central body to the periphery are given off filaments on the outer ends of which the chromatin particles accumulate. Finally, the entire central body disappears, instead of which there appear six separate bodies on the periphery of the parasite, after which the entire parasite breaks up into six individuals. . . . The parasite described by me should probably be referred to *Lankesterella*. I propose to name it *Lankesterella amania*.'

Awerinzew does not give any measurements of his parasite. From his figures it can be estimated that the diameter of the undivided parasite is about 1/25 to 1/17 of the long axis of the host-cell, while that of the schizont is 1/8. From blood-films of *Chamaeleon gracilis* in my collection I found that the long axis of its erythrocyte measures on the average about 20μ. Assuming the red-cells of *C. fisheri* to be equal in size to those of *C. gracilis*, the measurements of Awerinzew's parasite would be about $0{\cdot}8\mu$ to $1{\cdot}2\mu$ for the undivided stages, and $2{\cdot}5\mu$ for the schizont. It is thus considerably smaller than any of the known species of *Dactylosoma*, including the one described here. It also differs from members of this genus in other respects. In none of them is the trophozoite spherical with a central nucleus, nor is division of the type described by Awerinzew; moreover, the nucleus of *Dactylosoma* is always sharply differentiated from the cytoplasm. It is impossible from Awerinzew's description and figures to assign '*L. amania*' to any known group of haemoprotozoa.

Before any conclusion can be arrived at it will have to be re-investigated. At present all that can be done is to include this parasite among the already numerous intracellular organisms, *incertae sedis*, of unknown—animal or vegetable—affinities.

The present paper records for the first time a *Dactylosoma* in fish and thus extends the distribution of this genus to a second class of cold-blooded animals.

Owing to the similarity of certain stages of *Dactylosoma* to other haemococcidian parasites, some authors have included them in various other genera, such as *Haemogregarina*, *Lankesterella*, *Laverania*, etc. The question has been thoroughly discussed by Nöller (1913), who provided a list of synonyms of the frog-parasite, *D. ranarum*, the only form which has been thoroughly investigated.

DESCRIPTION

The total number of fish examined by me was fourteen, of which five—belonging to the four species named above—were infected.

The parasite was studied in blood-films and organ-smears fixed with methyl alcohol and stained with Giemsa's mixture.

All the stages of asexual development occur in the peripheral blood. Erythrocytes exclusively were found to be infected, and there was no evidence of the parasites affecting the host-cells in any way According to Nöller (1913), *D. ranarum* causes dehaemoglobinization of the red cells, while Mathis and Leger (1911) found them unaltered.

The various stages of the parasite observed can easily be arranged in the order of their development in the vertebrate host. The merozoites that had apparently recently penetrated into the host-cells measure 2·8μ by 0·9μ (fig. A, 1, 2, 3).

They are slightly larger than merozoites which have evidently just been formed and have not yet left the cell in which schizogony occurred (fig. B, 24).

These merozoites or trophozoites, as they may be termed at this stage, have the shape of short rods, usually slightly curved. One end of the body is somewhat narrower than the other, the nucleus being situated at the broader end. At a later stage the trophozoites

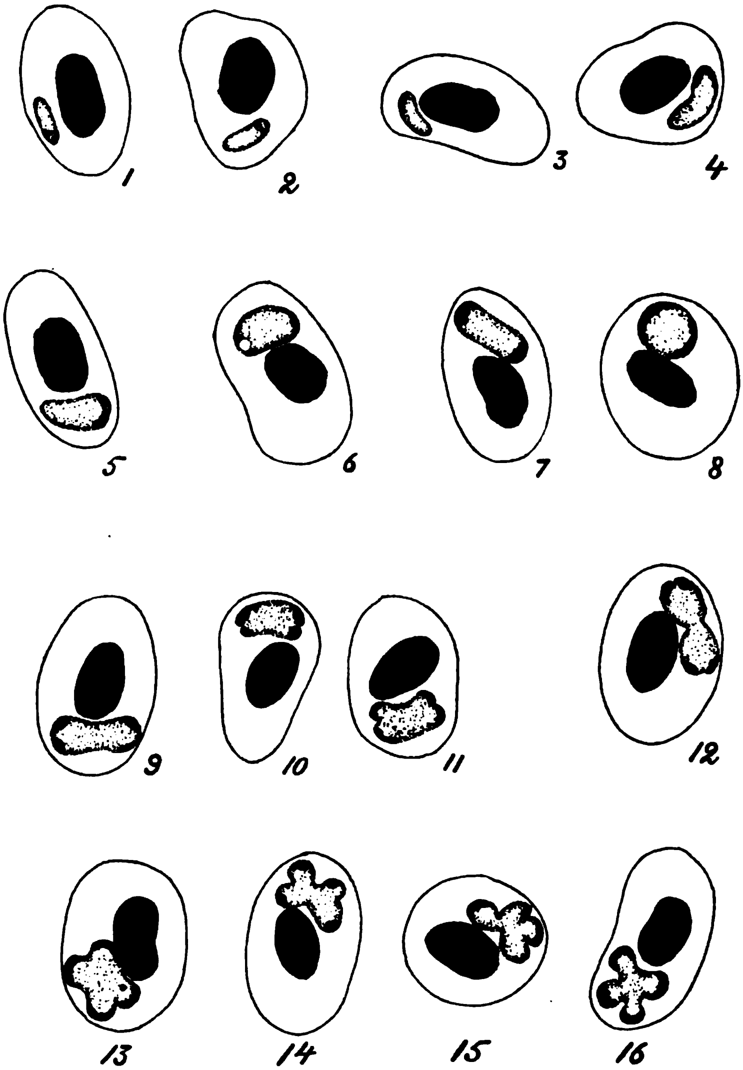

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FIG. A. *Dactylosoma mariae* sp.n. 1, 2, 3.—Merozoites; 4.—Trophozoite; 5, 6.—Early schizonts; 7, 8.—Beginning of schizogony: binucleate stage; 9, 10, 11.—Schizogony: tetranucleate stage; 12-16.—Schizogony: differentiation of merozoites. All × 2000.

increase in size, measuring from 3·8μ to 5·7μ in length, and from 1·9μ to 5·0μ in breadth. These forms are probably early schizonts (fig. A, 5, 6).

Schizogony is initiated by the division of the nucleus into two parts which become disposed at opposite poles (fig. A, 7, 8). Each nucleus then divides into two, the two pairs still retaining their polar arrangement (fig. A, 9-13). At this stage the body gradually becomes constricted in the middle, while a cleft appears at each pole separating the two nuclei. This process represents the differentiation of the merozoites corresponding to the four nuclei. As the division progresses the schizont loses its bipolar symmetry, the daughter-elements becoming more or less radially arranged (fig. A, 13-16). When the clefts between them reach the centre, the schizont assumes a more or less regular rosette shape, similar to that of some piroplasms, the daughter-forms being piriform with the nucleus at the broad distal end (fig. B, 18-20). Finally the connection between the merozoites is severed and they come to lie free in the cell (fig. B, 21, 22). There is no residue after division, the entire substance of the schizont being used up in the formation of the merozoites. The newly-formed merozoites have the original rosette arrangement, but later become scattered within the host-cell, while the body becomes elongated as in the young trophozoites (fig. B, 24).

The regular schizogony described is predominant and apparently represents the normal type, but occasionally deviations from this are encountered. Thus, a schizont may be fan-shaped with the nuclei disposed along the border of the broader side (fig. B, 23); the formation of the merozoites may not be synchronised, some developing more rapidly than others, and the process being more like true budding (fig. B, 17, 20, 24). The early stages of schizogony —before rosette formation—measure from 4·7μ to 5·7μ in length, and from 1·9μ to 3·8μ in breadth.

Schizogony in this parasite is characterised by the formation of *four* radially arranged merozoites. Neither more nor fewer have been observed. It differs from the *Dactylosoma* of frogs in that the latter has two types of schizogony. In one, numerous merozoites are produced and are arranged unilaterally, the fully-developed schizont having the appearance of a hand, the fingers of which are represented by the merozoites (hence the name of the genus). In the second

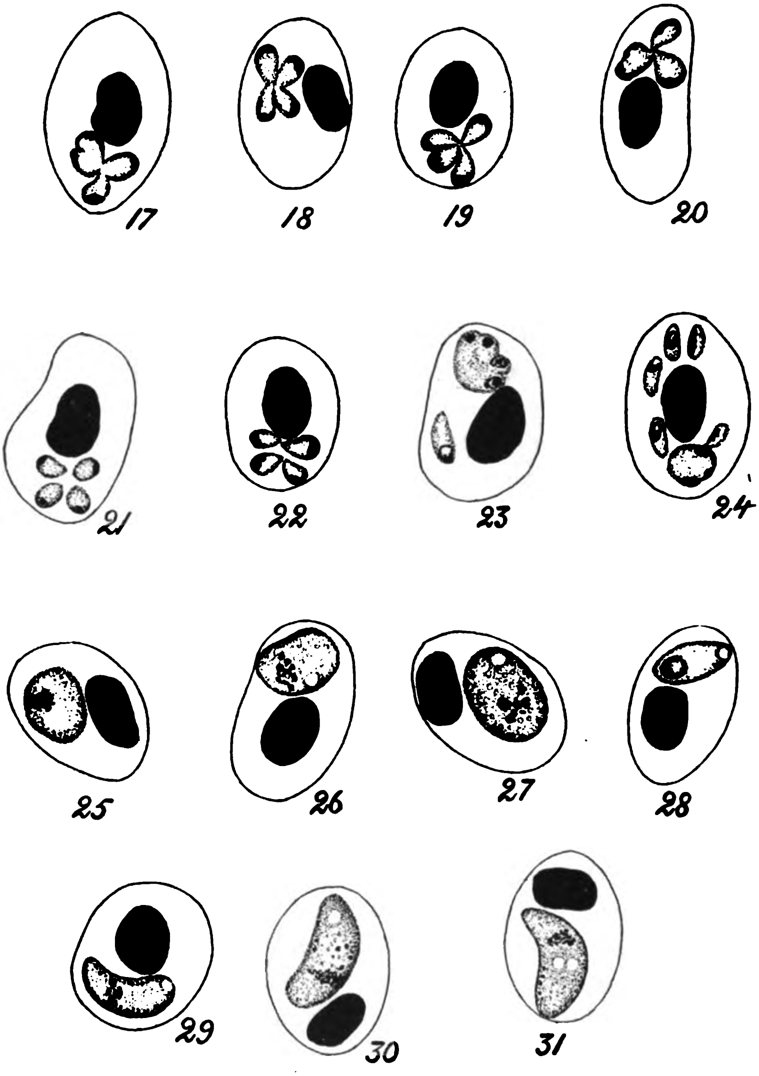

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Fig. B. *Dactylosoma mariae* sp.n. 17-20.—Final stages of schizogony: merozoites in rosette formation; 21-22.—Separation of merozoites; 23.—Double infection of host-cell: (*a*) schizont with unilateral arrangement of nuclei, and (*b*) a merozoite; 24.—Double infection of host-cell: (*a*) schizont showing unusual form of division: merozoite budding off. (*b*) Four sister-merozoites completely separated; 25.—Young female gametocyte; 26-27.—Mature female gametocytes; 28.—Young male gametocyte; 29, 30, 31.—Mature male gametocyte. All × 2000.

type a few merozoites only (four to six) are produced, their arrangement being more or less radial (Nöller, 1913: *Dactylosoma ranarum ;* Dutton, Todd and Tobey, 1907: ' *Drepanidium* ' (= *Dactylosoma*) from *Rana galamensis*). The second type of division corresponds to some extent with the type described here, for the parasite of fish, except that in the latter the number of merozoites is constantly four. A similar type of schizogony was recently described by Nigrelli (1929) in *Dactylosoma jahni* from a newt, *Triturus viridescens.* In this organism the number of merozoites produced is also four, arranged in the form of a rosette. *D. jahni*, however, differs from the parasite described here in that it has also other types of schizogony—one in which the merozoites are formed by successive budding, and another in which a residual body is left after schizogony.

The stages described represent the asexual cycle of development of the *Dactylosoma* of the fish. Apart from these there occur forms which have been interpreted as gametocytes in other members of the genus. These are of two types. In one the body is club-shaped and curved in the form of a crescent (fig. B, 29, 30, 31). The nucleus lies near the middle of the body and there are a few chromatin staining granules (volutin ?) scattered in the cytoplasm. These forms measure from 6·6μ to 8·5μ in length, and from 1·9μ to 3·5μ in breadth. In the second type the body is rounded, the nucleus is also near the middle of the body, and the dark granules are apparently absent. The cytoplasm of this type is more coarsely granular than in the preceding form (fig. B, 26, 27). The rounded forms measure from 5·7μ to 6·6μ in length, and from 3·8μ to 5·7μ in breadth. In both forms the cytoplasm stains more deeply than in the asexual stages and contains various minute granular inclusions. Another characteristic feature common to the two forms described is the presence of one or two small vacuoles, though these are occasionally seen in other stages (fig. A, 6). According to Nöller (1913) these vacuoles appear in fresh preparations of *D. ranarum* as refractile globules and probably represent oil-inclusions. The crescent-shaped form resembles the gametocytes of various haemosporidia, and it is probable—as interpreted by other authors—that the two forms are male and female gametocytes, the crescents, according to Nöller, being the male gametocytes and the rounded forms the female ones. The earlier stages of gametocytes differ from the fully developed ones only in smaller dimensions (fig. B, 25, 28).

Nothing is known regarding the intermediate hosts or method of transmission of any *Dactylosoma*.

Apart from the characters noted already (type of schizogony and number of merozoites), the *Dactylosoma* described here differs from other known members of the genus in the dimensions of the various stages. The characters of this parasite and its occurrence in a new class of host are sufficient to distinguish it as a new species for which the name *Dactylosoma mariae* sp.n., is proposed.

DIAGNOSIS AND SUMMARY

Systematic position. *Dactylosoma mariae* sp.n. (Coccidiida, near Piroplasmidea).

Habitat. Parasitic in erythrocytes of *Haplochromis nubilus*, *H. cinereus*, *H. serranus and H.* sp. (Pisces Teleostei).

Locality Victoria Nyanza, near Entebbe, Uganda.

Description. Asexual development (schizogony) and formation of gametocytes in the peripheral circulation of the host. Merozoites, 2·8μ by 0·9μ; trophozoites, 3·8-5·7μ by 1·9-5·0μ; schizogony resulting in production of four merozoites arranged in the form of a rosette, without residual body. Gametocytes of two types (♂ and ♀) crescent-shaped (6·6-8·5μ by 1·9-3·5μ) and rounded (5·7-6·6μ by 3·8-5·7μ). Intermediate host and sporogony unknown.

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